



CARNEGIE INSTITUTION
OF
WASHINGTON

YEAR BOOK No. 17

1918



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CHARLES L. HUTCHINSON.

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*Ex-officio member.

LIST OF PRESENT AND FORMER TRUSTEES.

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ROBERT S. BROOKINGS,	1910-	*S. WEIR MITCHELL,	1902-14
*JOHN L. CADWALADER,	1903-14	ANDREW J. MONTAGUE,	1907-
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CLEVELAND H. DODGE,	1903-	JAMES PARMELEE,	1917-
*WILLIAM E. DODGE,	1902-03	WM. BARCLAY PARSONS,	1907-
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*JOHN HAY,	1902-05	THEOBALD SMITH,	1914-
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*ABRAM S. HEWITT,	1902-03	WILLIAM H. TAFT,	1906-15
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*ETHAN A. HITCHCOCK,	1902-09	HENRY P. WALCOTT,	1910-
*HENRY HITCHCOCK,	1902-	WILLIAM H. WELCH,	1906-
*WILLIAM WIRT HOWE,	1903-09	*ANDREW D. WHITE,	1902-16
CHARLES L. HUTCHINSON,	1902-	EDWARD D. WHITE,	1902-03
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*WILLIAM LINDSAY,	1902-09	GEORGE W. WICKERSHAM,	1909-
HENRY CABOT LODGE,	1914-	ROBERT S. WOODWARD,	1905-
*SETH LOW,	1902-16	*CARROLL D. WRIGHT,	1902-08

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904:

The President of the United States.

The President of the Senate.

The Speaker of the House of Representatives.

The Secretary of the Smithsonian Institution.

The President of the National Academy of Sciences.

*Deceased.

ASSOCIATES OF THE INSTITUTION.

HEADS OF DEPARTMENTS OF RESEARCH.

LOUIS A. BAUER, *Director*, Department of Terrestrial Magnetism.
FRANCIS G. BENEDICT, *Director*, Nutrition Laboratory.
BENJAMIN BOSS, *Director*, Department of Meridian Astronomy.
CHARLES B. DAVENPORT, *Director*, Department of Experimental Evolution.
*ARTHUR L. DAY, *Director*, Geophysical Laboratory.
GEORGE E. HALE, *Director*, Mount Wilson Observatory.
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DANIEL T. MACDOUGAL, *Director*, Department of Botanical Research.
GEORGE L. STREETER, *Director*, Department of Embryology.
ALFRED G. MAYOR, *Director*, Department of Marine Biology.

OTHER INVESTIGATORS PRIMARILY CONNECTED WITH THE INSTITUTION.

WILLIAM CHURCHILL, Associate in Primitive Philology.
FREDERIC E. CLEMENTS, Associate in Ecology.
OLIVER P. HAY, Associate in Paleontology.
ELIAS A. LOWE, Associate in Paleography.
SYLVANUS G. MORLEY, Associate in American Archeology.
GEORGE SARTON, Research Associate in the History of Science.
ESTHER B. VAN DEMAN, Associate in Roman Archeology.
GEORGE R. WIELAND, Associate in Paleontology.

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HENRY BERGEN, Research Associate in Early English Literature.
V. BJERKNES (Geofysisk Institut, Bergen, Norway), Research Associate in Meteorology.
E. C. CASE (University of Michigan), Research Associate in Paleontology.
W. E. CASTLE (Harvard University), Research Associate in Biology.
T. C. CHAMBERLIN, (University of Chicago), Research Associate in Geology.
J. C. W. FRAZER (Johns Hopkins University), Research Associate in Chemistry.
JOHN F. HAYFORD (Northwestern University), Research Associate in Physics.
HENRY M. HOWE (Columbia University), Research Associate in Metallurgy.
J. C. KAPTEYN (University of Groningen), Research Associate of the Mount Wilson Solar Observatory.
L. B. MENDEL (Yale University), Research Associate in Physiological Chemistry.
T. H. MORGAN (Columbia University), Research Associate in Biology.
FRANK MORLEY (Johns Hopkins University), Research Associate in Mathematics.
H. N. MORSE (Johns Hopkins University), Research Associate in Chemistry.
F. R. MOULTON (University of Chicago), Research Associate in Mathematical Physics.
E. L. NICHOLS (Cornell University), Research Associate in Physics.
A. A. NOYES (Massachusetts Institute of Technology), Research Associate in Chemistry.
THOMAS B. OSBORNE (Connecticut Agricultural Experiment Station), Research Associate in Physiological Chemistry.
†H. L. OSGOOD (Columbia University), Research Associate in History.
T. W. RICHARDS (Harvard University), Research Associate in Chemistry.
H. C. SHERMAN (Columbia University), Research Associate in Chemistry.
EDGAR F. SMITH (University of Pennsylvania), Research Associate in Chemistry.
JOHN S. P. TATLOCK (Leland Stanford Junior University), Research Associate in Literature.

*Resigned October 1, 1918.

†Died September 11, 1918.

CONTENTS

	PAGE.
Organization, Plan, and Scope	IX
Articles of Incorporation	X-XII
By-laws of the Institution	XIII-XVI
Minutes	1-4
Report of the President of the Institution	5-30
Bibliography of publications relating to work of investigators, associates, and collaborators	31-40
Report of the Executive Committee	41-44
Financial Statement	45
Report of the Auditors	46-52
Reports on Investigations and Projects:	
Department of Botanical Research	55-88
Department of Embryology	89-102
Department of Experimental Evolution	103-118
Eugenics Record Office	119-126
Geophysical Laboratory	127-138
Department of Historical Research	139-147
Department of Marine Biology	149-172
Department of Meridian Astrometry	173-180
Mount Wilson Observatory	181-218
Nutrition Laboratory	219-232
Department of Terrestrial Magnetism	233-268
Other Investigations:	
Archeology:	
Morley, Sylvanus G.	269-276
Bibliography:	
Garrison, Fielding H.	276
Biology:	
Morgan, T. H.	277-278
Chemistry:	
Noyes, Arthur A.	279
Richards, Theodore W.	279-284
Sherman, H. C.	284-286
Smith, Edgar F.	286
Ecology:	
Clements, F. E.	287-297
Geology:	
Chamberlin, T. C.	297-298
History:	
Andrews, Charles M.	298
Osgood, Herbert L.	298
Literature:	
Bergen, Henry.	298
Tatlock, John S. P.	299
Mathematics:	
Morley, Frank.	299-300

Meteorology:	PAGE.
Bjerknes, V.	300-301
Nutrition:	
Osborne, Thomas B., and L. B. Mendel.....	302-310
Paleontology:	
Case, E. C.	310
Hay, Oliver P.	311-312
Wieland, G. R.	312-314
Physics:	
Barus, Carl.	314-315
Howe, Henry M.	315
Nichols, Edward L.	316-319
Zoology:	
Castle, W. E.	320

ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees herein-after appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES
OF THE
SEVENTEENTH MEETING OF THE BOARD OF
TRUSTEES

ABSTRACT OF MINUTES OF THE SEVENTEENTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington in the board room of the Administration Building, on Friday, December 13, 1918, and was called to order at 10^h10^m a. m. by the chairman, Mr. Root.

Upon roll-call, the following Trustees responded: Robert S. Brookings, Cleveland H. Dodge, Charles P. Fenner, Henry Cabot Lodge, William W. Morrow, James Parmelee, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, Henry P. Walcott, William H. Welch, Robert S. Woodward.

The minutes of the sixteenth meeting were approved as printed and submitted to members of the Board of Trustees.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments, Associates, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1919 were authorized:

Administration	\$55,000
Publication	60,000
Division of Publications	15,000
Departments of Research	753,490
Minor Grants	104,640
Index Medicus	12,000
Insurance Fund	25,000
Pension Fund	40,000
Reserve Fund	250,000
Special appropriation for Departments and Divisions of Research	150,000
	\$1,465,130

The following officers of the Board and the following members of committees were reelected for a period of three years:

Chairman, Mr. Root; Vice-Chairman, Mr. Charles D. Walcott; Secretary, Mr. Dodge.

Members of the Executive Committee: Messrs. Parsons, Paton, and Pritchett.

Members of the Finance Committee: Mr. Dodge (chairman) and Messrs. Pritchett and Wickersham.

Members of the Auditing Committee: Mr. Brookings (chairman) and Messrs. Hutchinson and Wickersham.

Dr. George L. Streeter, acting Director of the Department of Embryology, was appointed Director of this Department, from January 1, 1919.

The name of the Mount Wilson Solar Observatory was changed to read "Mount Wilson Observatory of the Carnegie Institution of Washington."

The meeting adjourned at 11^h45^m a. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1918.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1918, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the seventeenth annual administrative report of the Institution and is presented under the following principal heads:

1. Salient events of the year.
2. Researches of the year.
3. Financial records.
4. Publications of the year.
5. Bibliographical appendix.

SALIENT EVENTS OF THE YEAR.

It should go without saying that the absorbing events of the year for the Institution, as well as for all similar establishments, are direct and indirect consequences and exigencies of the world war. The existence of such organizations depends on stable governments, on freedom of thought and action within limits approved by experience and sanctioned by law, and on opportunities for that sort of reflection which leads to the development of discoveries and advances. That these fundamental requirements are now at

Participation in
World War.

stake is as evident to the investigator as to the statesman, to the publicist, or to the soldier; and it is unnecessary to explain that the reactions of the members of the Institution to the changed world environment are not less normal than those of contemporaries in other walks of life. Biological continuity asserts itself here as well as elsewhere and affords no new ground for the vagaries of occultism with which the Institution is frequently invested in popular fancies. As a matter of fact, and of printed though hitherto unpublished record, at the first meeting of the Executive Committee of the Institution held after the formal entrance of the United States into the pending conflict, namely, April 19, 1917, the following self-explanatory resolutions were unanimously adopted:

"Resolved, That, in view of the existing national emergency, the President of the Carnegie Institution of Washington be and hereby is authorized to tender to the United States Government the services of associates and members of departmental and divisional staffs of the Institution for such duties as they may be severally best qualified to perform; and that, similarly, the departmental organizations of the Institution, together with personnel, equipment, and laboratory facilities, be offered to the Government for such special work as may be appropriately performed by them in the interests of national defense.

"Resolved, That, upon request from the United States Government or any of its authorized agents for such special service or work, the President be and hereby is authorized to comply therewith, so far as practicable, with the understanding that associates and members, during periods of detail to the service of the Government, shall be granted leaves of absence from the Institution with full pay, deductions therefrom being made in each case to the amount of compensation, if any, which may be received from the Government.

"Resolved, That the President, in his discretion, be and hereby is authorized, in the case of any associate or member of the Institution who enlists in the service of the Government, to give assurances of the maintenance of the status in the Institution of such associate or member and of a continuance of compensation not exceeding the rate of salary received from the Institution at the time of entrance into the service of the Government."

Copies of these resolutions were promptly transmitted to the President of the United States and as promptly acknowledged, and they have served as a working basis whereby a majority of the experts and a large share of the income of the Institution have been turned to account in response to requests from the Government.

The time for publication of a history of the activities thus enlisted and of the numerous and varied services thus rendered

has not arrived; no chapter concerning them is yet complete; most of them are still in the stages of development, while some of them have been only recently inaugurated. The work in question is involved with and is evolving with many concomitant activities of governmental departments and other organizations, so that the activities of the Institution and its staffs are not immediately and obviously separable. Moreover, much of this work is of a confidential nature, concerning which the Government is not only entitled to current control but to precedence in historical record. But while this is neither the time nor the place for a full account of these unusual occupations of the Institution, it appears not inappropriate and not untimely to cite two of them, drawn from widely separated fields of investigation, which have led to results of international as well as national importance and which help, in ways popularly unexpected but rationally predictable, to justify the existence of research establishments. These two cases may serve to indicate the kinds of work in which the staffs and associates of the Institution are now engaged and to show how easy it is to pass from what appear to be abstract investigations to the most concrete and utilitarian applications of them.

To men of science it was well known two years prior to April 1917 that the United States would encounter a serious shortage of optical glass if compelled to resort to arms in the rapidly expanding conflict; for there would be immediately needed large numbers of telescopes, field glasses, gun-sights, range-finders, periscopes, and other optical adjuncts, without which the ordnance departments of the Army and Navy would be myopic if not blind. Provision for this emergency was forecast by both the National Research Council and the Naval Consulting Board. It was known to them that the Geophysical Laboratory of the Institution had made special studies of silicates during something like a decade before the date referred to, and that in staff and in determinative appliances this was probably the best-equipped establishment in existence to make the preliminary investigations and to furnish the superintendence in manufacture essential to the develop-

Production of
Optical Glass by
Geophysical
Laboratory.

ment of a nearly new industry in the United States. Formal authorization to engage in this enterprise was given by the following resolutions, approved by the Executive Committee April 19, 1917:

"Resolved, That the Director of the Geophysical Laboratory be and hereby is authorized and requested, upon application from the United States Government or any of its agents, to undertake an investigation of the properties and technique in production of optical glass, and to secure cooperation in so far as practicable and essential with governmental and private agencies engaged in the study or production of this material.

"Resolved, That a sum not to exceed \$10,000 be and hereby is allotted to the Geophysical Laboratory, from the special appropriation of \$100,000 authorized by the Board of Trustees at its meeting of December 15, 1916, for needs of the various departments and divisions of research of the Institution, to defray costs of special appliances and traveling expenses incident to the proposed investigation of optical glass and its production."

For about one year from the date of these resolutions the entire staff and resources of the Laboratory, along with extra allotments of funds to pay necessary traveling and subsistence expenses, were devoted to the several branches of the work. This work embraced chemical and optical analyses of available specimens of the many kinds of optical glass in use; extensive searches for and tests of materials used not only in the glass itself but in the pots in which it is fused; critical studies of the requisite processes of manipulation and temperature control; and the surmounting of obstacles set up by trade secrets, craftsmanship, commercial rivalries, and by the inevitable friction of administrative machinery not wholly in conformity with the law of the conservation of energy.

Referring to the reports and correspondence of the Director of the Laboratory for details concerning this novel and arduous undertaking, it may suffice here to state summarily that within a year the production of uncut optical glass was raised from less than a ton per month to more than 100 tons per month; that this work has required, in addition to numerous laboratory researches, the virtual conduct of three manufacturing plants located in different cities; that the Director and staff of the Laboratory have penetrated the secrets in which the processes of manufacture have been held hitherto and supplanted them by straightforward methods which require only competent knowledge for their suc-

cessful application; and finally, that the cost of this work to the Institution includes the amount of the annual budget of the Laboratory supplemented by about 20 per cent of this amount to pay for overtime service and for subsistence and transportation required in the procurement of materials and in the operation of distant factories.

The other illustrative example of the war activities of the Institution is furnished by the Nutrition Laboratory. About seven years ago this organization undertook, as part of its general program, a series of special experiments on the effects of fasting and the intermediate gradations of undernutrition. The extremes of fasting were studied very thoroughly in the remarkable case of Levanzin, who submitted himself to a continuous fast of 31 days while under constant and critical observation in the Laboratory by its staff and by several specialists of the medical profession.* In the meantime, while many collateral researches bearing directly or indirectly on the effects in question have been made by the Laboratory, it remained to conduct a prolonged series of experiments on groups of men subjected to systematic and continuous observation while pursuing their daily vocations and while subsisting on a common and definitely restricted diet. It is easy to see that the results of such an investigation may throw much light on the problems arising from the existing and prospective world shortage in food supplies. To what extent the efficiency of men may be impaired when obliged to work strenuously while subsisting on short rations, how long they may hold out under such conditions, what limits may be safely approached, and what are the danger signals or the physiological criteria to be observed, are questions of immediate practical importance in almost every country as well as of great theoretical interest in the narrower circles of research establishments.

In his endeavor to secure quantitative data which may afford answers to these and other questions, the Director of the Laboratory was fortunate in enlisting the cooperation of the officials

*A detailed account of this investigation is given in Publication 203 of this Institution.

and of two squads of students (a dozen men each) of the Y. M. C. A. College of Springfield, Massachusetts. These squads, while maintaining their regular college work, were put on a low diet and kept under observation and experiment continuously for about four months, from October 1917 to February 1918. They were subjected to pathological, psychological, muscular, and calorimetric tests, so that a complete history for the duration of the investigation was obtained for each individual as well as for the group to which he belonged.

The results of these researches are of prime present importance and they were promptly communicated to the governmental authorities. The observations reveal many unexpected facts and record some surprisingly low levels of physiological stability. They show, among other things, that the normal adult man may subsist for some months on a severely restricted diet and during this time may undergo marked losses in body weight and in nitrogenous reserves without serious impairment of his mental and muscular efficiency. A full report of this work is now in press as Publication No. 280. That a project involving so many details, so much machinery, and the closest cooperation of so many individuals could be successfully carried out in these disturbing times may be taken as an evidence of the unity in altruistic purpose of our American contemporaries as well as an indication of the unity in altruistic endeavor of the staff of the Nutrition Laboratory.

When the world war broke out in 1914 the non-magnetic ship *Carnegie* was engaged in her third cruise, which led to the highest north latitude she has attained, namely, 79° 52', off the northwest coast of Spitzbergen. Sailing thence southward, and touching at Reykjavik, Iceland, August 24, 1914, she learned of the changed order of international affairs; but her program in the north Atlantic was completed without difficulty and she returned to her base station, Greenport, New York, October 9, and to Brooklyn, New York, October 21, 1914.

Return of
Ship Carnegie.

Refitting during the winter of 1914-15, the *Carnegie* left the base station just mentioned March 9, 1915, for a more extended cruise (No. IV), which was expected to require about three years. Sailing down the west Atlantic and through the Panama Canal, she left the Pacific port of Balboa April 12 and arrived at Honolulu May 21. Stopping there for a few weeks for land work and to swing ship, she arrived at Dutch Harbor, Alaska, July 20. Leaving this port August 5, she made a long voyage of 89 days and 8,865 miles in the western Pacific to Lyttleton, New Zealand, without stopping at any intermediate point. After an interval of 33 days for shore work and for refitting, she left Lyttleton December 6 for a circuit of the south polar region, mainly between the parallels of 50° and 60° south latitude. This circuit was completed April 1, 1916, in 118 days, the total distance traversed being 17,084 miles. It is remarkable that a long voyage in this stormy region should have proved highly successful. Although precipitation was recorded on five-sixths of the days, magnetic declinations (variations) were observed on every day but one, while magnetic dip and intensity (or strength of the earth's field) were observed on every day. Errors in magnetic variation given by the best sailing charts previously published were found to be as great for some places as 12° to 16° .

After a stay at Lyttleton for instrumental comparisons at Christchurch Magnetic Observatory and for overhauling and refitting, the *Carnegie* left this port May 17, 1916, for Pago Pago, Samoa, where she arrived June 7. Thence she sailed June 19 for Port Apra, Guam, which was reached July 17, and thence to San Francisco, where she arrived September 21, the courses having been arranged to intersect, as frequently as practicable, the previous courses of the *Galilee* and the *Carnegie*. After a stay of five weeks at San Francisco, the ship set sail November 1, 1916, bound for Easter Island, which was reached December 24. Thence, on January 2, 1917, she set out for Buenos Aires by way of the eastern Pacific, making a large loop intersecting the earlier voyages in the central Pacific at many points. No stops were made. Cape Horn was rounded February 17, and the harbor of

Buenos Aires was reached March 2. Here the ship was held until the following December by reason of anticipated dangers from German raiders, floating mines, and submarines in the Atlantic.

In respect to the case presented by the *Carnegie*, the Director of the Department of Terrestrial Magnetism recalls attention to an instructive historical analogy which is at the same time equally instructive by reason of its relentless antilogy. When in the latter part of the eighteenth century Great Britain was at war with France and the United States and when the distinguished explorer, Captain Cook, was expected to return from what proved to be his last voyage of discovery, the French Government issued orders to its marine officers to the effect that "such discoveries being of general utility to all nations, it is the King's pleasure that Captain Cook shall be treated as a commander of a neutral and allied power." About the same time Franklin, then representing the United States in France, issued (March 10, 1779) "a passport for Captain Cook to all captains and commanders of armed ships acting by commission from the Congress of the United States of America, now in war with Great Britain," instructing them to "treat the said Captain Cook and his people with all civility and kindness, affording them, as common friends to mankind, all the assistance in your power, which they may happen to stand in need of." Up to April 1917 the results of the ocean magnetic surveys of the *Carnegie*, in aid of navigation, had been transmitted promptly to the German marine authorities as well as to all other national authorities issuing ocean sailing charts, yet no such immunity or reciprocity as obtained in the eighteenth century has been extended by the Central Empires in these generally more enlightened years of the twentieth century.

The program of the cruise in question included a series of loops in the Atlantic during the summer and autumn of 1917 and a return to a home port near the end of that year. But soon after the United States became a belligerent in the world war it was determined to hold the *Carnegie* at Buenos Aires pending the advent of safer conditions. These appeared assured when, on December 4, 1917, the vessel set out for the Pacific on a new cruise (No. V), which might bring her either to San Francisco or

to an Atlantic home port by way of the Panama Canal, as circumstances might require. In the meantime, Commander J. P. Ault, who had traversed 63,401 miles of cruise IV, as originally planned, had been called home and assigned to other duties. He was succeeded by Dr. H. M. W. Edmonds, who had long served as surgeon and as a member of the navigating staff of the vessel. Rounding Cape Horn again, she reached Talcahuano, Chile, a distance of 3,863 miles, in 38 days, or on January 11, 1918. Leaving Talcahuano January 23, she made a loop to the westward of the Juan Fernandez Islands and returned to Callao, Peru, February 22, 1918. Thence she sailed March 29, making a detour south of the Galapagos Islands, arriving at the Pacific port of Balboa on April 24, and passing through the Panama Canal on May 2. Since there appeared at that time to be no dangers in the way of a return to an Atlantic port, she proceeded from Cristobal on May 11 by the shortest route to Newport News, arriving there June 4, having eluded the submarine then off the Virginia Capes by a margin of about 20 miles. Six days later she was laid up at a wharf at the port of Washington, D. C., and is now out of commission, awaiting a return of conditions which will permit a resumption of her international mission in aid of navigation and in extension of our knowledge of the magnetic properties of the earth. Since this vessel was launched, in June 1909, she has traversed in her surveys an aggregate of 189,176 nautical miles, or somewhat more than eight times the circumference of the earth. Of this aggregate, 102,429 miles were traversed under the command of W. J. Peters, 72,961 under J. P. Ault, and 13,786 under H. M. W. Edmonds.

The following historical statement is taken from the printed but unpublished minutes of the Executive Committee of the Institution, for the meeting of January 11, 1918. Upon motion, this memorandum and the accompanying resolutions were approved and ordered to be spread upon the minutes of the meeting:

Gift of Eugenics
Record Office.

“Definite recognition of the science of life, now designated by the term biology, dates essentially from the publication of Darwin’s Origin

of Species in 1859. The foundations for this culminating work were laid by not less than twenty centuries of discontinuous and unorganized efforts by the devotees to anatomy, pathology, botany, geology, and more recently, physiology, zoology, and paleontology; but it was reserved for Darwin, Wallace, Spencer, and their coadjutors to discover and to establish the principles which unify all these collateral sciences in the generalization called the doctrine of evolution. The term biology was popularized by Spencer in 1865; and in the brief interval which has since elapsed demonstrable biological knowledge has grown with astonishing rapidity to an aggregate which constitutes one of the most important advances made in the progress of our race.

"It was a natural and logical sequence, therefore, in alignment with this progress, that the Carnegie Institution of Washington should have established three departments of research devoted severally to investigations in different fields of the rapidly enlarging domain of biological science. And it is similarly consonant with the spirit of the age and with the aims of the Institution that the Eugenics Record Office should have developed in close affiliation with the Department of Experimental Evolution and with the Biological Laboratory of the Brooklyn Institute of Arts and Sciences at Cold Spring Harbor, Long Island. The stimulus for progress brought to both these organizations by the Director of the Department of Experimental Evolution, the formation of a eugenics section under his secretaryship in the American Breeder's Association, and the sympathetic interest in all these enterprises shown by Mrs. E. H. Harriman, are among the earlier favoring influences which led to the establishment of the Eugenics Record Office in 1910. In April of that year Mrs. Harriman purchased for the purposes of the project a tract of land of about eighty acres, near Cold Spring Harbor, and in October following the Office was installed in a dwelling house on this land.

"In accordance with Mrs. Harriman's preference it was determined at the outset that the work of the Eugenics Record Office should be work of research. It was recognized that the first need is for knowledge and that when this is gained applications will follow in due course. The principal objects of the Office are the following:

"a. To serve eugenical interests in the capacity of a repository and a clearing house.

"b. To build up an analytical index of the inborn traits of American families.

"c. To train field workers to gather data of eugenical import.

"d. To maintain a field staff actually engaged in gathering such data.

"e. To cooperate with other institutions and with persons concerned with eugenical study.

"f. To investigate the manner of inheritance of specific human traits.

"g. To publish the results of researches.

"In December 1912 the valuable adjunct of a board of expert directors of the Office was organized, consisting of Alexander Graham Bell (chairman), William H. Welch (vice-chairman), Irving Fisher, Lewellys F. Barker, and E. E. Southard, with Charles B. Davenport as secretary. A year later T. H. Morgan was added to this board. Dr. Davenport has served continuously as resident director and H. H. Laughlin as superintendent of the Office. In the meantime, many investigations have been made, extensive records have been collected and classified, and many publications have been issued, among the more noteworthy of which latter are three volumes published by the Carnegie Institution of Washington. The permanent staff of the Office now includes 14 persons and its annual budget amounts to \$25,000. There are 6 buildings on the land, namely, a dwelling house, a fire-proof office, a stable, a garage, a pumping plant, and a water tower.

"Although Mrs. Harriman has furnished the main financial support of the Office from its foundation and the sole support in recent years, other friends of the enterprise have generously given aid for maintenance and for certain special purposes.*

"Since October 1915 Mrs. Harriman has expressed a desire to place the Eugenics Record Office on a more permanent basis and has offered the real estate and the records of the establishment, along with a gift of \$300,000 in securities, to the Carnegie Institution of Washington. The acceptance of this offer was recommended to the Board of Trustees of the Institution by resolution of the Executive Committee adopted at its meeting of November 19, 1917. This recommendation was unanimously approved by the Board of Trustees at their meeting of December 14, 1917, and the President was authorized to arrange for formal receipt of the securities and a deed for the real estate involved. Accordingly, the Chairman of the Finance Committee and the President of the Institution received from Mrs. Harriman at her residence, 1 East 69th Street, New York, N. Y., on Friday, Decem-

*When the Eugenics Record Office was turned over to the Carnegie Institution of Washington an inventory showed property of the estimated value of \$140,062.61, distributed as follows: real estate, \$80,680; furniture and equipment, \$7,488.82; archives, \$45,209.98; library, \$1,606.85; supplies, \$5,076.96.

The records also showed that the total amount spent by Mrs. E. H. Harriman on the Eugenics Record Office, including cost of property, new buildings, improvements, and maintenance, from October 1, 1910, to December 31, 1917 (data supplied by Robert R. Dunnett, auditor of the estate of E. H. Harriman), was \$246,832.82. Other sources and items of income received prior to December 31, 1917, are the following: John D. Rockefeller, for field work, \$21,650; Bleeker Van Wagenen, for publications, \$1,737.32; W. E. D. Stokes, for field work, \$200; Mrs. Lucy W. James, for field lecturer, \$2,500.

The total cost of the enterprise up to December 31, 1917, is therefore \$272,920.14. Deducting the amount of the inventory of January 1, 1918, it is seen that the entire cost of the researches of the Eugenics Record Office from its establishment on October 1, 1910, to December 31, 1917, a period of seven years and three months, is \$132,857.53.

ber 27, 1917, the securities in question and the data essential for a draft of a deed conveying the real estate.

"Resolved, That in accepting from Mrs. E. H. Harriman her gift of the Eugenics Record Office and the accompanying provision for its maintenance, the Executive Committee of the Carnegie Institution of Washington desire to record their admiration for the philanthropic discernment and the enlightened liberality which have led her to found this altruistic enterprise, and to express their sense of obligation to maintain and to pursue its researches under the auspices of the Institution for the benefit alike of our contemporaries and of our successors.

"Resolved, That a fund to be called the Harriman Fund be and hereby is established and that the United States Trust Company of New York be requested to set apart in this fund the securities (aggregating \$300,000, par value) recently presented to the Institution by Mrs. E. H. Harriman as a part of her gift of the Eugenics Record Office."

Near the beginning of the present fiscal year, namely, November 17, 1917, Dr. Franklin Paine Mall, Director of the Department of Embryology, died at Baltimore, Maryland, in the fifty-fifth year of his age.

Death Losses
of the Year.

Mall was born at Belle Plaine, Iowa, September 28, 1862. His preparatory education was had in public and private schools and his first academic degree was obtained in the school of medicine of the University of Michigan at the early age of 21 years. He later pursued special courses of study at Heidelberg, Leipzig, and Johns Hopkins Universities. After serving as instructor in pathology at Johns Hopkins University and as professor of anatomy successively in Clark University and in the University of Chicago, he became professor of anatomy of the Johns Hopkins Medical School in 1893. He held this position actively until the end of 1912 and in an advisory capacity up to the time of his death.

In response to proposals submitted by Dr. Mall during the year 1912, he was appointed Research Associate of the Institution March 15, 1913; and by resolution of the Trustees December 11, 1914, the Department of Embryology, under his direction, was formally established. To this work he brought the resources not only of a highly original and productive mind, but also his remarkable collection of human embryos. Under the exacting professional standards of his administration the work of this department immediately assumed advanced rank, while the

researches already published and in press assure the department a position of leadership in a branch of biology which sustains fundamental relations to the older and highly wrought sciences of anatomy, physiology, and pathology, and the closest relations likewise to the less definite but widely comprehensive science of anthropology.

Professor Mall not only attained preeminence among American leaders in anatomy, but the originality and the generality of his researches are held by competent judges to entitle him to a position of equality along with the pioneers and the masters in this ancient science, whose history, according to Mall's own estimate, is typified by the names of Aristotle, Vesalius, Bichat, and His. To this remarkable capacity as an investigator he added that of a great teacher of men, not in the didactic sense of the word, but in his ability to make students do their own thinking. He understood well that little formal instruction was needed in his laboratory in the presence of evolving discoveries and advances. But Mall was much more than a specialist in the branches of biology to which he devoted the most of his time and attention. He was an uncommonly accomplished man of the world so far as knowledge of men, motives, and methods can supply versatility in fiscal affairs. He was a man of remarkably clear insight; he sought always to see the universe as it is, and he was much more keenly aware than most of us that limitations exist on every hand. He was an ideally typical man of science; modest in realizing the relatively small progress man has made in discovering his relations to the plexus of phenomena of which he forms a part; confident of the continuity while conscious of the slowness of that progress; and facing his colleagues and contemporaries generally with the same frankness and the same truthfulness with which he approached the problems presented by his favorite fields of research.

The Institution is called upon to record the loss also of another highly productive investigator in the death, on September 11, 1918, of Professor Herbert Levi Osgood, Research Associate in early American history since October 19, 1911.

Professor Osgood was born at Canton, Maine, April 9, 1855. He was a graduate of Amherst College, and pursued graduate studies in turn at Yale, Berlin, and Columbia universities, attaining the doctorate at the last of these in 1889, while in the meantime pursuing a sustaining vocation as teacher in the public schools of Brooklyn. Early in his professorial career he set for himself the arduous task of a determinative study of the political genesis of the American Republic. To this he devoted himself with unflagging industry and zeal to the end of his life, and his achievements have won for him a position of eminence in this field of inquiry and exposition. His history of "The American Colonies in the Seventeenth Century," in three volumes, published in 1904 to 1907, is the standard work for the earlier part of the period in question; and this he had planned to supplement by a corresponding history of the eighteenth century brought down to the beginning of the American Revolution. Happily for his contemporaries and for his successors, the manuscripts for this extended work, which is expected to comprise four additional volumes, were nearly finished at the time of his death, and arrangements have already been made with his heirs to complete for publication at an early date this fitting memorial to a life dedicated with rare fidelity and singleness of purpose to the higher and more enduring objects of historical research.

RESEARCHES OF THE YEAR.

As indicated in a preceding section, the normal activities of the Institution have undergone profound changes in many respects since April 1917, and these changes have followed closely the rapid development of our national participation in the portentous combat. About two-thirds of the members of the investigatory staffs, including Departments of Research and Research Associates, have responded to calls for governmental work, while nearly all of them have been deflected more or less from their accustomed occupations. The demands on the Institution for expert knowledge, technical skill, and unusual services, requiring in many cases special investigations and much collaboration, have received first attention. The variety and extent of these

demands and the readiness of response to them are matters of record in the minutes of the Executive Committee, in the special reports from the Departments of Research and from Research Associates, and in the extensive correspondence relative to this emergency work; so that, when the proper time arrives, a complete account of these unexpected activities may be rendered. At the moment it need be said only that these activities have taken precedence over all others.

Thus it has happened that many investigations have been suspended, that the staffs of some departments of research are at work wholly or in part for the Government, and that many individuals have left their peaceful occupations in order to assist in meeting the military exigencies of the hour. The national needs for specialists of many kinds have drawn most heavily, naturally, on the younger men of the Institution. The departments of research and the Research Associates have lost thus, temporarily it is hoped, many of their most effective and promising men.

Nevertheless, in spite of the state of commotion in which the world now finds itself, and in which all organizations must participate to a greater or less extent, the primary objects of the Institution have been well sustained. This is especially the case with the departments of research, for although their programs have been disarranged or suspended, and although many individuals of their staffs have been transferred to more pressing duties, the departmental organizations remain essentially intact. Hence, following the plan adopted in 1917, no noteworthy departures from customary characteristics will be found in the current Year Book. The reports of departmental heads and of research associates and the annual bibliography are printed as usual and are confined essentially to the conventional work of the Institution. Special reports concerning emergency work for the Government have been rendered and are on file in the office of administration, but although these reports relate to services which are in some instances of extraordinary national value, and although they represent activities requiring relatively large aggregates of time, effort, and costs, their publication, for reasons already indicated, is not deemed appropriate here.

FINANCIAL RECORDS.

It is an anomalous and somewhat disturbing circumstance that while public attention has been generally focussed on certain aspects of the finances of the Institution and of similar recently endowed establishments, little or no serious public attention has been given to the conditions essential to the financial stability and permanence of such organizations. Thus it does not appear possible to cite any generally recognized authorities who have considered these conditions and evolved adequate maxims or theories for guidance in conformity with them. The prevalent impressions with respect to these matters seem to be impulsive and poetic rather than reflective and constrained. Statistical data and the ulterior consequences they foreshadow and entail are held to be only disagreeable concomitants of trade, commerce, and accountancy. Like Carlyle, the majority of our contemporaries are interested in the rhetoric rather than in the arithmetic of fiscal affairs. But along with this overconfident optimism of the majority generated by concentration of attention on the broadly altruistic aspects in question, there arise also, quite too commonly, certain misapprehensions fraught with the gravest of dangers, not only to existing organizations, but to those also which are likely to be established in the future with the return of nations to peaceful pursuits. Lack of reflection and reluctance to undertake the labor imposed by unattractive realities lead easily to the erroneous conclusions that endowed establishments may proceed in their evolution with the same liberty of action accorded to their founders as individuals, by methods of unrestricted choice, caprice, or paternalism, and without special legal warrant or financial accountability. At present the majorities almost everywhere are imbued with favorable impulses toward altruistic foundations, but it is conceivable that this attitude may be reversed at any time in any community or state wherein such misapprehensions spring up. In fact, it is not altogether improbable, in the light of passing events, that some such foundations may be taxed out of existence on the plea that they are subject to inadequate legal, financial, and social constraint.

It appears not inappropriate, therefore, to recall public attention to the following facts:

(1) That the Institution exists under articles of incorporation granted by the Congress of the United States in an act approved April 28, 1904.

(2) That the affairs of the Institution are administered by a board of trustees to whom the Founder, by his deed of trust, has given full and unreserved authority for action within limits prescribed by law and warranted by the recorded history of mankind.

(3) That the original endowment of the Institution was \$10,000,000; that this was increased by the Founder's gifts of \$2,000,000 in 1907 and of \$10,000,000 in 1911, his endowment thus aggregating \$22,000,000.

(4) That, with the exception of a few relatively small receipts* of funds from other sources, the sole source of funds available for expenditure by the Institution is the interest on its endowment, which now amounts, in round numbers, to \$1,112,000.

(5) That the financial accounts of the Institution are audited annually by public auditors whose reports appear annually also in the Year Books.

In addition, it may be stated that, since February 1906, there have been issued monthly, printed financial statements showing the status of every principal asset and account of the Institution for the date; the items of receipts and disbursements for the preceding month; a summary of the receipts and disbursements from the beginning of the fiscal year to date; and a similar summary of receipts and disbursements from the foundation of the Institution to date. Although these special financial statements have not been published, complete files of them may be seen in bound volumes kept in the office of administration and a copy of any current number may be had on application.

**Financial Statement
for Fiscal Year
1917-1918.** The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted at the end of the year are shown in detail in the following statement:

*The largest of these is \$150,000 per annum furnished by the Carnegie Corporation of New York during the years 1917 and 1918.

Financial Statement for fiscal year 1917-1918.

Object of appropriation.	Balances unallotted Oct. 31, 1917.	Appropriation Dec. 14, 1917.	Revertments Nov. 1, 1917, to Oct. 31, 1918.	Total.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1918.
Large grants.		\$709,180		\$709,180.00	\$709,180.00	
Minor grants.	\$2,178.53	100,440	\$63,924.57	166,543.10	158,339.00	\$8,204.10
Publication.	18,684.60	60,000	7,329.27	86,013.87	77,410.22	8,603.65
Administration.		53,000		53,000.00	53,000.00	
Reserve fund.		250,000		250,000.00	250,000.00	
Insurance fund.		25,000		25,000.00	25,000.00	
Pension fund.		40,000		40,000.00	40,000.00	
Total.	20,863.13	1,237,620	71,253.84	1,329,736.97	1,312,929.22	16,807.75

The aggregates of receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is \$15,969,328.22.

Aggregates of financial receipts.

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902.	\$250,000.00	\$9.70			\$1,825.52	\$251,835.22
1903.	500,000.00	5,867.10	\$2,286.16		101.57	508,254.83
1904.	500,000.00	33,004.26	2,436.07	\$999.03		536,439.36
1905.	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906.	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907.	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908.	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909.	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910.	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911.	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912.	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913.	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914.	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915.	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916.	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917.	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918.	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
Total.	13,195,025.37	681,641.75	138,350.54	109,499.65	*1,844,810.91	15,969,328.22

*Of this amount \$1,394,335 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918; \$51,265.74 from the Colburn Estate in 1916; and \$370,000 from the Carnegie Corporation of New York in 1917 and 1918.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) investments in bonds; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor projects, special projects, research associates, and assistants.	Publications.	Administration.	Total.
1902.	.....	.....	\$4,500.00	.....	\$27,513.00	\$32,013.00
1903.	\$100,475.00	.....	137,564.17	\$938.53	43,627.66	282,605.36
1904.	196,159.72	\$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905.	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906.	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907.	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908.	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909.	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910.	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911.	51,921.79	463,609.75	63,048.80	37,580.17	45,455.80	661,616.31
1912.	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913.	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914.	861,915.73	817,894.52	107,456.05	44,670.55	44,159.54	1,876,096.39
1915.	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916.	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917.	505,473.49	695,813.07	97,526.69	62,884.61	48,766.29	1,410,464.15
1918.	528,815.55	693,780.00	170,220.74	44,394.83	49,118.76	1,486,329.88
Total.	4,387,179.05	7,881,555.85	1,758,751.98	688,412.45	744,045.12	15,459,944.45

The following list shows the departments and divisions to which appropriations were made by the Trustees at their last annual meeting and the amounts allotted from these by the Executive Committee during the year:

Department of Botanical Research.....	\$49,109.00
Department of Embryology.....	35,192.00
Eugenics Record Office.....	25,000.00
Department of Experimental Evolution.....	59,790.00
Geophysical Laboratory.....	92,000.00
Department of Historical Research.....	38,900.00
Department of Marine Biology.....	20,400.00
Department of Meridian Astrometry.....	31,426.00
Nutrition Laboratory.....	46,124.00
Division of Publications.....	12,000.00
Solar Observatory.....	154,033.00
Department of Terrestrial Magnetism.....	145,206.00
Aggregate for Minor Grants.....	153,339.00
Aggregate for Publications.....	60,410.22
Total.....	922,929.22

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended since the foundation of the Institution:

*Schedule of real estate, equipments, and publications.**

Administration:		
Building, site, and equipment.....		\$333,173.15
Department of Botanical Research (Sept. 30, 1918):		
Buildings and grounds.....	\$31,816.94	
Laboratory and library.....	15,272.68	
Operating appliances.....	18,407.41	
		65,497.03
Eugenics Record Office (Sept. 30, 1918):		
Library, furniture, and operating appliances.....	9,465.31	
Archives.....	45,360.27	
Buildings and land.....	129,563.59	
		184,389.17
Department of Experimental Evolution (Sept. 30, 1918):		
Buildings, office, library, and grounds.....	124,140.90	
Laboratory apparatus.....	9,829.01	
Field.....	19,479.00	
		153,448.91
Geophysical Laboratory (Sept. 30, 1918):		
Building, library, operating appliances.....	166,985.67	
Laboratory apparatus.....	72,140.01	
Shop equipment.....	10,771.16	
		249,896.84
Department of Historical Research (Sept. 30, 1918):		
Office.....	2,426.72	
Library.....	3,471.15	
		5,897.87
Department of Marine Biology (Sept. 30, 1918):		
Vessels.....	31,180.43	
Buildings, docks, furniture, and library.....	11,975.36	
Apparatus and instruments.....	8,368.20	
		51,523.99
Department of Meridian Astrometry (Sept. 30, 1918):		
Apparatus and instruments.....	2,394.34	
Operating.....	1,603.69	
		3,998.03
Nutrition Laboratory (Sept. 30, 1918):		
Building, office, and shop.....	120,453.18	
Laboratory apparatus.....	23,859.02	
		144,312.20
Mount Wilson Solar Observatory (Aug. 31, 1918):		
Buildings, grounds, road, and telephone line.....	173,901.92	
Shop equipment.....	37,242.86	
Instruments.....	417,049.25	
Furniture and operating appliances.....	131,749.14	
Hooker 100-inch reflector.....	503,966.77	
		1,263,909.94
Department of Terrestrial Magnetism (Sept. 30, 1918):		
Building, site, and office.....	131,558.67	
Vessel and survey equipment.....	130,798.84	
Instruments, laboratory, and shop equipment.....	70,012.09	
		332,369.60
Publications:		
Stock on hand at sale price (Oct. 31, 1918).....	272,896.25	
Outstanding accounts (Oct. 31, 1918).....	2,385.76	
		275,282.01
		3,063,698.74

*Real estate and equipment, original cost.

The cost of maintenance of the Administration Building, including the items of fuel, lighting, janitorial services, maintenance of grounds, repairs, and other incidental expenses, has been, for 1910, \$2,981.65; for 1911, \$2,641.53; for 1912, \$2,919.89; for 1913, \$2,601.15; for 1914, \$3,251.08; for 1915, \$3,955.60; for 1916, \$2,870.51; for 1917, \$3,272.50; and for 1918, \$3,891.80.

Expenses of Main-
tenance of Admin-
istration Building.

PUBLICATIONS.

The publication of 17 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of \$49,500.00. The following list gives the titles and names of the authors of the publications issued during the year; it includes 17 volumes, with an aggregate of 3,073 octavo pages and 1,120 quarto pages; 31 additional volumes are now in press.

Publications
Authorized and
Issued during the
Year.

List of publications issued during the year.

- Year Book No. 16, 1917. Octavo, 358 pages, 1 plate, 5 figures.
Index Medicus, Second Series, Vol. 15, 1917. Octavo, 816 pages.
No. 213. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. IX. Quarto, iii+362 pages, 105 plates, 14 figures.
Mayer, Alfred G. Ecology of the Murray Island Coral Reef. 48 pages, 19 plates, 9 figures.
Vaughan, Thomas Wayland. Some Shoal-water Corals from Murray Island (Australia), Cocos-Keeling Islands, and Fanning Island. 185 pages, 73 plates, 2 figures.
Vaughan, Thomas Wayland. Some Shoal-water Bottom Samples from Murray Island, Australia, and Comparisons of them with Samples from Florida and the Bahamas. 54 pages, 2 plates, 2 figures.
Goldman, Marcus Isaac. Composition of Two Murray Island Bottom Samples according to Source of Material. 14 pages.
Mann, Albert. Diatoms from Murray Island, Australia. 2 pages.
Cushman, Joseph A. Foraminifera from Murray Island, Australia. 2 pages, 1 plate.
Howe, Marshall A. Calcareous Algæ from Murray Island, Australia, and Cocos-Keeling Islands. 6 pages, 2 plates.
Dole, Richard B., and Alfred A. Chambers. Salinity of Ocean Water at Fowey Rocks, Florida. 16 pages, 1 plate, 2 figures.
Wells, Roger C. The Solubility of Calcite in Contact with the Atmosphere, and Its Variation with Temperature. 3 pages.
Vaughan, Thomas Wayland. The Temperature of the Florida Coral-reef Tract. 20 pages, 3 figures.
Cary, L. R. Gorgonaceæ as a Factor in the Formation of Coral Reefs. 20 pages, 6 plates.
No. 227. Contributions to Embryology, Nos. 20, 21, 22, and 23. Vol. VII. Quarto, 136 pages.
Streeter, George L. The Histogenesis and Growth of the Otic Capsule and its Contained Periotic Tissue-spaces in the Human Embryo. (Contribution No. 20.) 50 pages, 4 text figures, 4 plates.
Van Der Stricht, O. The Genesis and Structure of the Membrana Tectoria and the Crista Spiralis of the Cochlea. (Contribution No. 21.) 32 pages, 4 plates.
Wheeler, Theodora. Study of a Human Spina Bifida Monster with Encephaloceles and other Abnormalities. (Contribution No. 22.) 23 pages, 4 plates.
Ingalls, N. W. A Human Embryo before the Appearance of the Myotome. (Contribution No. 23.) 24 pages, 5 text figures, 4 plates.

- No. 245. Hedrick, Henry B. Interpolation Tables or Tables of Proportional Parts, containing the products to the nearest unit of all numbers from 1 to 100 by each hundredth from 0.01 to 0.99 and of all numbers from 1 to 1,000 by each thousandth from 0.001 to 0.999. Folio, 149 pages.
- No. 246. Albany Zone Catalogues for the Epoch 1900. Quarto, xxiii+249 pages.
Boss, Lewis. Catalogue of 8276 Stars between 20° and 41° South Declination.
Roy, Arthur J. Catalogue of 2800 Stars between 2° of South and 1° of North Declination
- No. 249. Barus, Carl. The Interferometry of Reversed and Non-reversed Spectra. (Part II.) Octavo, 146 pages, 97 figures.
- No. 252. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. XII. Octavo, v+258 pages, 29 plates, 28 figures.
Fowler, H. W. Some Amphibians and Reptiles from Porto Rico and the Virgin Islands. 15 pages, 11 plates, 6 figures.
Silvester, Charles F. Fishes New to the Fauna of Porto Rico, with Descriptions of Eight New Species. 8 pages, 4 plates.
Gudger, E. W. Oral Gestation in the Gaff-topsail Catfish, *Felichthys felis*. 28 pages, 4 plates.
Gudger, E. W. *Sphyræna barracuda*: Its Morphology, Habits, and History. 56 pages, 7 plates, 5 figures.
Bowman, H. H. M. Botanical Ecology of the Dry Tortugas. 30 pages, 6 plates, 7 figures.
White, E. Grace. The Origin of the Electric Organs in *Astroscopus guttatus*. 44 pages, 7 plates, 1 figure.
Mayer, A. G. Toxic Effects due to High Temperature. 6 pages.
Mayer, A. G. Nerve-conduction in Diluted and in Concentrated Sea-water. 5 pages, 1 figure.
Ball, S. C. The Migration of Insects to Rebecca Shoal Light-Station and the Tortugas Islands, with special reference to Mosquitoes and Flies. 30 pages.
Cary, Lewis R. A Study of Respiration in *Alcyonaria*. 7 pages.
McClendon, J. F. On Changes in the Sea and their Relation to Organisms. 47 pages, 8 figures.
- No. 253. Ivens, Walter G. Dictionary and Grammar of the Language of Sa'a and Ulawa, Solomon Islands. With appendices. Octavo, vii+249 pages, 12 plates, 1 figure.
- No. 254. Davenport, Frances G. European Treaties bearing on the History of the United States and Its Dependencies, to 1648. Octavo, vi+387 pages.
- No. 260. Davis, Paul B., and Collaborators. Studies on Solution in its relation to Light-Absorption, Conductivity, Viscosity, and Hydrolysis; A Report upon a Number of Experimental Investigations carried out in the Laboratory of the late Professor Harry C. Jones. Octavo, 144 pages, 26 figures.
- No. 261. Benedict, Francis G., and Thorne M. Carpenter. Food Ingestion and Energy Transformations with special reference to the Stimulating Effect of Nutrients. Octavo, 355 pages, 3 figures.
- No. 264. Sturtevant, A. H. An Analysis of the Effects of Selection. Octavo, 66 pages, 1 plate, 14 text figures, 38 tables.
- No. 266. Miles, Walter R. Effect of Alcohol on Psycho-Physiological Functions. Octavo, 144 pages, 15 figures, 32 tables.
- No. 267. Smith, Edgar F., and Walter K. Van Haagen. The Atomic Weights of Boron and Fluorine. Octavo, v+65 pages, 6 text figures.
- No. 269. Johnson, Duncan S. The Fruit of *Opuntia fulgida*. A Study of Perennation and Proliferation in the Fruits of Certain Cactaceæ. Octavo, 62 pages, 13 plates.
- No. 271. Contributions to Embryology, Nos. 24, 25, 26. Vol. VIII. Quarto, 198 pages.
Streeter, George L. The Developmental Alterations in the Vascular System of the Brain of the Human Embryo. (Contribution No. 24.) 38 pages, 5 plates, 12 figures.
Cowdry, E. V. The Mitochondrial Constituents of Protoplasm. (Contribution No. 25.) 120 pages, 1 plate, 9 figures.
Kunitomo, Kanae. The Development and Reduction of the Tail and the Caudal End of the Spinal Cord. (Contribution No. 26.) 36 pages, 4 plates, 2 text figures.

Sales of Publications and Value of those on hand.

The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903...	\$2,256.91	\$29.25	.....
1904...	2,370.47	52.85	\$12.75
1905...	2,562.76	44.75	431.44
1906...	2,970.56	37.60	1,341.52
1907...	3,676.71	56.50	2,292.89
1908...	3,406.19	99.65	4,371.67
1909...	4,821.85	73.01	6,287.21
1910...	4,470.50	100.70	5,899.05
1911...	4,440.21	85.50	6,366.55
1912...	4,652.14	61.65	6,782.34
1913...	4,992.02	75.95	7,140.69
1914...	5,079.16	49.65	6,273.59
1915...	5,010.21	47.60	5,239.98
1916...	4,382.19	46.60	8,115.37
1917...	4,616.21	51.55	7,253.59
1918...	4,324.29	21.10	5,575.61
Total.	64,032.38	933.91	73,384.25

At the end of the fiscal year there are on hand 99,189 volumes of miscellaneous publications and Year Books, having a sale value of \$253,630.25; also 35,895 numbers of the Index Medicus, having a sale value of \$19,266.00. The total value of publications on hand is therefore \$272,896.25.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 171,195 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. Three hundred and seventy-two volumes, embracing a total of 102,758 pages of printed matter, have thus far been issued by the Institution.

CARNEGIE INSTITUTION OF WASHINGTON.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the seventeen years from 1902 to 1918.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,269	4,193
Total..	372	71,928	30,830	102,758

APPENDIX.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS,
ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications proceeding from work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 27-28).

- ADAMS, WALTER S. Some stellar investigations at the Mount Wilson Observatory. *Jour. des Observateurs*, vol. 2, 65-68 (1918).
- , and ALFRED H. JOY. The luminosities and parallaxes of five hundred stars. First list. *Astrophys. Jour.*, vol. 46, 313-339 (1917); *Mt. Wilson Contr.*, No. 142.
- , ———. Some spectral characteristics of Cepheid variables. *Proc. Nat. Acad. Sci.*, vol. iv, 129-132 (1918); *Mt. Wilson Communications*, No. 53.
- , ———. Ten spectroscopic binaries. *Pubs. A. S. P.*, vol. 29, 259 (1917).
- , ———. Two stars with remarkable radial velocities. *Pubs. A. S. P.*, vol. 29, 259 (1917).
- , ———. The spectrum of Nova Monocerotis. *Pubs. A. S. P.*, vol. 30, 162 (1918).
- , ———. Note on Nova Monocerotis. *Pubs. A. S. P.*, vol. 30, 193 (1918).
- , ———. Note on the identification of certain bright lines in the spectrum of α Ceti. *Pubs. A. S. P.*, vol. 30, 193-194 (1918).
- , ———. Mount Wilson observations of the spectrum of Nova Aquilæ No. 3. *Pubs. A. S. P.*, vol. 30, 251-253 (1918).
- , ———. Spectrographic observations of W Ursæ Majoris. Read at 22d meeting, *Amer. Astron. Soc.* (1918).
- , and HARLOW SHAPLEY. Note on the Cepheid variable SU Cassiopeiæ. *Astrophys. Jour.*, vol. 47, 46-50 (1918); *Mt. Wilson Contr.*, No. 145.
- , and CHARLES E. ST. JOHN. The green corona line at the 1918 eclipse. Read at 22d meeting, *Amer. Astron. Soc.* (1918).
- , and GUSTAF STRÖMBERG. Radial velocity and absolute magnitude. Comments on Professor Perrine's article. *Astrophys. Jour.*, vol. 47, 189-192 (1918); *Mt. Wilson Contr.*, No. 146.
- , ———. The orbit of the spectroscopic binary Boss 46. *Astrophys. Jour.*, vol. 47, 329-335 (1918); *Mt. Wilson Contr.*, No. 149.
- AULT, J. P. Sea surface-temperature and meteorological observations made on the *Carnegie* during her sub-Antarctic cruise, December 6, 1915, to April 1, 1916. *Terr. Mag.*, vol. 22, No. 4, 183-189 (Dec. 1917).
- . Cruises III and IV of the yacht *Carnegie* in the Arctic and sub-Antarctic regions. (Paper presented before the Philosophical Society of Washington, March 30, 1918.) [Abstract] *Jour. Wash. Acad. Sci.*, vol. 8, No. 11, 370 (June 4, 1918).
- AVERY, B. T., jr. See BLAKESLEE, A. F.; HARRIS, J. A.
- BARNETT, S. J. On electromagnetic induction and relative motion: II. *Phys. Rev.*, vol. 12, No. 2, 95-114 (Aug. 1918).
- . Magnetization by rotation. *Science*, n. s., vol. XLVIII, No. 1239, 303-309 (Sept. 27, 1918).
- BARUS, CARL. Experiments with Foucault pendulum. *Science*, n. s., vol. XLV, 265-270 (1917).
- . Theoretical relations in the interferometry of small angles. *Proc. Nat. Acad. Sci.*, vol. III, 563-565 (1917).
- . Displacement interferometry in connection with U-tubes. *Proc. Nat. Acad. Sci.*, vol. III, 334-339 (1917).
- . Transverse displacement interferometry. *Proc. Nat. Acad. Sci.*, vol. III, 360-365 (1917).
- . Direct and reversed spectrum methods for measuring small angles. *Proc. Nat. Acad. Sci.*, vol. III, 665-672 (1917).
- . Interference methods of measuring the elasticities of small bodies. *Proc. Nat. Acad. Sci.*, vol. III, 693-696 (1917).
- . Equations of the rectangular interferometer. *Proc. Nat. Acad. Sci.*, vol. IV, 13-19 (1918).
- . Types of achromatic fringes. *Proc. Nat. Acad. Sci.*, vol. IV, 132-133 (1918).
- . Interference of pencils which constitute the remote divergence of a slit. *Proc. Nat. Acad. Sci.*, vol. IV, 134-136 (1918).
- BAUER, L. A. Relation between the secular variation of the Earth's magnetism and solar activity. *Terr. Mag.*, vol. 23, No. 1, 1-22 (Mar. 1918); No. 2, 61-68 (June 1918).
- . Proposed magnetic and allied observations during the total eclipse of June 8, 1918. *Terr. Mag.*, vol. 23, No. 1, 32 (Mar. 1918); *Science*, n. s., vol. XLVII, No. 1220, 486-487 (May 17, 1918).
- . Return of the *Carnegie*, June 1918. *Terr. Mag.*, vol. 23, No. 2, 45-46 (June 1918).

- BAUER, L. A. The claims of international science. *Terr. Mag.*, vol. 23, No. 3, 150 (Sept. 1918).
- , H. W. FISK, and S. J. MAUCHLY. Results of magnetic and allied observations during the solar eclipse of June 8, 1918. *Terr. Mag.*, vol. 23, No. 3, 95-110 (Sept. 1918).
- BENEDICT, CORNELIA GOLAY, and F. G. BENEDICT. The energy content of extra foods. *Boston Med. and Surg. Jour.*, vol. CLXXIX, 153 (1918).
- BENEDICT, FRANCIS G. A portable respiration apparatus for clinical use. *Boston Med. and Surg. Jour.*, vol. CLXVIII, 667 (1918).
- . Physiological effects of a prolonged reduction in diet on twenty-five men. *Proc. Amer. Phil. Soc.*, vol. VII, 479 (1918).
- . Physiological effects of a prolonged reduction in diet on twenty-five men. *Jour. Roy. Army Med. Corps* (Aug. 1918).
- . Effets physiologiques d'une réduction prolongée du régime alimentaire expérimentée sur vingt-cinq sujets. *Bul. de la Soc. Sci. d'Hyg. Alimentaire*, vol. VI, 422 (1918).
- , WALTER R. MILES, PAUL ROTH, and H. MONMOUTH SMITH. The effects of a prolonged reduced diet on twenty-five college men. I: On basal metabolism and nitrogen excretion. II: On neuro-muscular processes and mental condition. III: On efficiency during muscular work. *Proc. Nat. Acad. Sci.*, vol. IV, 149 (1918).
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- BICHOWSKY, F. RUSSELL V. The necessary physical assumptions underlying a proof of the Planck radiation law. *Phys. Rev.*, vol. 11, 58-65 (1918).
- . The color of inorganic compounds. *Jour. Amer. Chem. Soc.*, vol. XL, 500-508 (1918).
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REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1918.

During this year the Executive Committee held nine meetings, printed reports of which have been mailed to each Trustee of the Institution.

Upon the adjournment of the meeting of the Board of Trustees of December 14, 1917, the members of the Executive Committee met and organized by the election of Mr. Walcott as Chairman for 1918, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1917-1918, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and an outline of suggested appropriations for the year 1918. The Executive Committee hereby approves the report and the recommendations of the President as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 14, 1917, instructed the Executive Committee to appoint Messrs. Arthur Young & Co., of Chicago and New York, to audit the accounts of the Institution for the fiscal year ending October 31, 1918. The report of the auditor, including a balance sheet showing the assets and liabilities of the Institution on October 31, 1918, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

No vacancies exist in the membership of the Board of Trustees.

The terms of service of the following officers of the Board of Trustees will expire at the coming annual meeting: Mr. Root, as Chairman of

the Board; Mr. Walcott, as Vice-Chairman; Mr. Dodge, as Secretary; Messrs. Parsons, Paton, and Pritchett, as members of the Executive Committee; Messrs. Dodge, Pritchett, and Wickersham, as members of the Finance Committee, and Messrs. Brookings, Hutchinson, and Wickersham, as members of the Auditing Committee.

CHARLES D. WALCOTT, *Chairman*.

CLEVELAND H. DODGE.

WM. BARCLAY PARSONS.

STEWART PATON.

HENRY S. PRITCHETT.

ELIHU ROOT.

HENRY WHITE.

ROBERT S. WOODWARD.

November 14, 1918.

REPORT OF THE EXECUTIVE COMMITTEE.

45

RECEIPTS.		DISBURSEMENTS.	
<i>Interest</i>		<i>Investment</i>	
Endowment.....	*13,448.38.44	Securities.....	\$4,069,833.39
Reserve Fund.....	374,907.36	Collection charges.....	3,909.03
Insurance Fund.....	41,779.70	Administration Building and site.....	309,915.69
Colburn Fund.....	10,699.75		
Pension Fund.....	891.87	<i>Pension Fund</i>	\$4,383,658.11
		<i>Insurance</i>	250.
		<i>Grants</i>	3,270.94
		Large.....	7,881,555.85
		Minor.....	1,703,751.98
<i>Colburn Fund</i>	52,015.74		
		<i>Publication</i>	9,585,307.83
		<i>National Research Council</i>	688,412.45
		<i>Administration</i>	55,000.
<i>Sales of Publications</i>		Trustees.....	42,307.36
Index Medicus.....	64,032.38	Executive Committee.....	27,130.21
Year Book.....	933.91	Honorariums.....	17,319.81
Miscellaneous.....	73,384.25	Salaries.....	440,351.90
		Shipping publications.....	40,862.95
		Rent, surety, telephone.....	31,406.36
		Equipment.....	14,679.10
		Stationery.....	13,257.62
		Postage, express.....	21,697.84
		Printing.....	†47,589.79
		Office expenses.....	11,078.06
		Buildings and grounds	
		Supplies, janitor.....	20,317.94
		Fuel, light, water.....	8,321.13
		Organization (1902).....	1,825.52
		Plans and option.....	5,166.46
		Seal (1903).....	555.60
		Miscellaneous.....	70.23
			743,937.88
		<i>Refund</i>	
		Publication.....	20.25
		Index Medicus.....	86.99
			107.24
		<i>Cash in Banks</i>	15,459,944.45
			509,383.77
			15,969,328.22
<i>Redemption and Sale of Bonds</i>	1,395,609.37		
	15,969,328.22		

*Including interest from Income and Building Fund bonds. †Including Year Books.

REPORT OF AUDITORS.

ARTHUR YOUNG & COMPANY

ACCOUNTANTS AND AUDITORS, 71 BROADWAY (EMPIRE BUILDING)

Auditors' Certificate

Hon. ELIHU ROOT,
*Chairman of the Board of Trustees,
Carnegie Institution of Washington,
Washington, D. C.*

SIR: We have audited the books and records of the CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1918. The income from the investments and other sources has been accounted for and all disbursements evidenced by properly approved vouchers. The bank balances have been verified. The securities belonging to the various funds as stated in Statement *C* have been examined and found to be in order. The details of the expenditures of the Departments of Research have been audited by the Bursar of the Institution and were not examined by us.

We certify that the accompanying Balance Sheet and the statements annexed thereto correctly show the financial condition of the Institution at October 31, 1918.

Yours very truly,

(Signed) ARTHUR YOUNG & Co.

NEW YORK, *November 30, 1918.*

THE CARNEGIE INSTITUTION OF WASHINGTON, WASHINGTON, D. C.

Statement A—Balance Sheet—October 31, 1918

[illegible]

THE CARNEGIE INSTITUTION OF WASHINGTON, WASHINGTON, D. C.

Statement C—Schedule of Investments as at October 31, 1918.

Par value.	Securities.	Investment value.	Total.
<i>Endowment</i>			
\$21,200,000	U. S. Steel Corporation, Registered 50-year 5% Gold Bonds, Series A, B, C, D, E, F, due April 1, 1951.....	\$21,200,000.00	
175,000	Chicago, Milwaukee & Puget Sound Railway Company, First Mortgage 4% Gold Bonds, due January 1, 1949.....	159,268.00	
14,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989.....	13,953.75	
325,000	Lehigh & Lake Erie Railroad Company, First Mortgage 4½% 50-year Gold Bonds, due March 1, 1957.....	331,568.30	
237,000	New York City 4½% Registered Bonds, due March 1, 1963.....	253,557.50	
150,000	South & North Alabama Railroad Company, Consolidated Mortgage 5% Bonds, due August 1, 1936.....	160,875.00	
500	United States of America Third Liberty Loan.....	500.00	\$22,119,722.55
<i>Colburn Fund</i>			
20,000	Acker, Merrall and Condit Company, Debenture 6% Bonds.....	13,600.00	
4,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage, 4½% Bonds due 1989.....	4,070.00	
8,000	Park and Tilford Company, Sinking Fund, Debenture 6% Bonds.....	6,400.00	
50,000	Pennsylvania Railroad Co., General Mortgage 4½% Bonds, due June 1, 1965.....	51,925.00	
42,000	Pittsburg, Shawmut & Northern Railroad, First Mortgage, 4% Bonds, due February 1, 1952.....	4,200.00	
5,000	United States of America Second Liberty Loan of 1917 Converted.....	5,000.00	
2,000	United States of America Third Liberty Loan of 1918.....	2,000.00	
2,000	United States of America Fourth Liberty Loan of 1918.....	2,000.00	89,195.00
<i>Harriman Fund</i>			
100,000	Southern Pacific Company, San Francisco Terminal, First Mortgage 4% Bonds, due 1950.....	100,000.00	
200,000	Chicago, Burlington & Quincy R. R. Co., Illinois Division, 4% Bonds, due 1949.....	200,000.00	300,000.00
<i>Insurance Fund</i>			
28,000	American Telephone & Telegraph Company, 4½% Convertible Bonds.....	\$28,978.00	
50,000	Atchison, Topeka & Santa Fe Railway Company, General Mortgage, 100-year, 4% Registered Gold Bonds, due 1995.....	50,056.25	
25,000	Bell Telephone Company of Canada, Debenture 5% Bonds, April 1, 1925.....	24,760.00	
30,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage, 4% Bonds, due March 1, 1958.....	28,237.50	
22,667,500	 <i>Carried forward</i>	132,031.75	22,508,917.55

Statement C—Schedule of Investments as at October 31, 1918 (Cont'd).

\$22,667,500	Brought forward.....	\$132,031.75	\$22,508,917.55
1,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989.....	995.00	
21,000	Great Northern Railway First and Refunding 4½% Bonds, due 1961.....	20,944.00	
21,000	Illinois Central Railroad Company, Refunding Mortgage 4% Bonds, due November 1, 1955.....	19,008.75	
24,000	Pennsylvania Railroad Company, Consolidated Mortgage, 4½% Bonds, due Aug. 1, 1960.....	25,095.01	
4,000	United States of America Second Liberty Loan of 1917 Converted.....	4,000.00	
29,500	United States of America Third Liberty Loan of 1918.....	29,500.00	
3,000	United States of America Fourth Liberty Loan of 1918.....	3,000.00	234,574.51
<i>Reserve Fund</i>			
50,000	American Telephone & Telegraph Company, Collateral Trust 4% Bonds, due 1929.....	45,500.00	
96,000	American Telephone & Telegraph Company, 4½% Convertible Bonds.....	99,456.25	
100,000	Baltimore & Ohio Railroad Company, General and Refunding 5% Bonds, due 1995...	102,375.00	
50,000	Central Pacific Railway Company, First Refunding Mortgage 4% Registered Gold Bonds, due 1949.....	48,250.00	
150,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage, 4% Bonds, due March 1, 1958.....	141,263.75	
15,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989.....	14,925.00	
120,000	Chicago and North-Western General Mortgage 3½% Bonds, due November 1, 1987..	100,300.00	
155,000	General Electric, 5% Gold Debenture Bonds.	158,213.47	
48,000	Great Northern Railway Company, First and Refunding Mortgage 4½% Bonds, due 1961.....	48,109.25	
100,000	Illinois Central Railroad Company, Refunding 4% Bonds, due 1955.....	89,668.75	
280,000	Interborough Rapid Transit Company, First Refunding Mortgage 5% Bonds, due 1966.	276,701.00	
50,000	Lake Shore & Michigan Southern Railway Company, Registered 25-year 4% Gold Bonds, due September 1, 1928.....	47,000.00	
50,000	Long Island Railroad Company, Refunding Mortgage 4% Bonds, due 1949.....	48,285.00	
50,000	New York, Westchester & Boston Railway Company, First Mortgage 4½% Bonds, due 1946.....	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy Collateral), Joint 4% Bonds, due 1921.....	49,037.50	
50,000	Northern Pacific Railway Co., General Lien Railway and Land Grant 3% Bonds, due January 1, 2047.....	33,101.25	
50,000	Oregon-Washington Railroad & Navigation Company, First and Refunding 4% Mortgage Bonds, due 1961.....	46,375.00	
24,235,000	Carried forward.....	1,397,748.72	22,743,492.06

Statement C—Schedule of Investments as at October 31, 1918 (Cont'd).

\$24,235,000	Brought forward.....	\$1,397,748.72	\$22,743,492.06
30,000	Pennsylvania Railroad Company, General Mortgage 4½% Bonds, due June 1, 1965. . .	29,837.50	
101,000	Pennsylvania Railroad Company, Consoli- dated Mortgage, 4½% Bonds, due August 1, 1960.....	105,608.12	
100,000	Southern Pacific Railroad First Refunding Mortgage, 4% Bonds, due 1955.....	92,148.75	
140,000	Union Pacific Railroad Co. First Lien and Refunding 4% Bonds, due June 1, 2008....	128,722.50	
112,500	United States of America First Liberty Loan, Second Converted 4½% due 1947..	112,500.00	
85,500	United States of America Second Liberty Loan of 1917 Converted.....	85,500.00	
153,000	United States of America Third Liberty Loan of 1918.....	153,000.00	
245,000	United States of America Fourth Liberty Loan of 1918.....	245,000.00	2,350,065.59
<u>\$25,202,000</u>			<u>\$25,093,557.65</u>

THE CARNEGIE INSTITUTION OF WASHINGTON, WASHINGTON, D. C.

*Statement D—Schedule of Real Estate and Equipment as at October 31, 1918.**Administration*

Building, site, and equipment.....		\$333,173.15
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Department of Botanical Research (September 30, 1918)

Buildings and Grounds.....	\$31,816.94	
Laboratory and Library.....	15,272.68	
Operating Appliances.....	18,407.41	65,497.03

Eugenics Record Office (September 30, 1918)

Library, Furniture and Operating Appliances.....	\$9,465.31	
Archives.....	45,360.27	
Buildings and Land.....	129,563.59	184,389.17

Department of Experimental Evolution (September 30, 1918)

Buildings, Office, Library, and Grounds.....	\$124,140.90	
Laboratory Apparatus.....	9,829.01	
Field.....	19,479.00	153,448.91

Geophysical Laboratory (September 30, 1918)

Building, Library, Operating Appliances.....	\$166,985.67	
Laboratory Apparatus.....	72,140.01	
Shop Equipment.....	10,771.16	249,896.84

Department of Historical Research (September 30, 1918)

Office.....	\$2,426.72	
Library.....	3,471.15	5,897.87

Department of Marine Biology (September 30, 1918)

Vessels.....	\$31,180.43	
Buildings, Docks, Furniture, and Library.....	11,975.36	
Apparatus and Instruments.....	8,368.20	51,523.99

Department of Meridian Astrometry (September 30, 1918)

Apparatus and Instruments.....	\$2,394.34	
Operating.....	1,603.69	3,998.03

Nutrition Laboratory (September 30, 1918)

Building, Office, and Shop.....	\$120,453.18	
Laboratory Apparatus.....	23,859.02	144,312.20

Mount Wilson Solar Observatory (August 31, 1918)

Buildings, Grounds, Road, and Telephone Line.....	\$173,901.92	
Shop Equipment.....	37,242.86	
Instruments.....	417,049.25	
Furniture and Operating Appliances.....	131,749.14	
Hooker 100-inch Reflector.....	503,966.77	1,263,909.94

Department of Terrestrial Magnetism (September 30, 1918)

Building, Site, and Office.....	\$131,558.67	
Vessel and Survey Equipment.....	130,798.84	
Instruments, Laboratory, and Shop Equipment.....	70,012.09	332,369.60

\$2,788,416.73

REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1918, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.

D. T. MACDOUGAL, DIRECTOR.

The general conditions affecting the activities of the Department have made it seem advisable to collate and summarize the results of all work in a stage sufficiently advanced to justify publication. Members of the staff, therefore, have narrowed the scope of their experimentation and devoted attention chiefly to the preparation of manuscripts. Exploration and field work have been reduced to a minimum, the chief effort in this direction being the desert studies in Australia begun by Dr. W. A. Cannon in May 1918, and the survey of the Santa Lucia Mountains, a coastal range running southward from the Coastal Laboratory, by Dr. Forrest Shreve. Collaboration with workers outside the Institution has been less than in any preceding year.

As may be seen, much attention has been devoted to the study of fundamental problems in carbohydrate metabolism and to the imbibitional action of the plant colloids in growth. All of the water-relations of organisms have necessarily been taken into consideration. An adequate physical explanation of the origin and action of the spinose and succulent plants constituting the characteristic desert vegetation has been found. Important geographic and ecological results have been formulated as described in the following paragraphs.

IMBIBITION AND GROWTH.

Development of Conceptions included in Growth, by D. T. MacDougal.

Three main conceptions concerning growth and its developmental aspects in plants are to be met in the history of physiology in the last half century. The first or earliest, that of special stuffs or substances which come in the developmental and seasonal crises and which were taken to be necessary for growth and for the origination and development of reproductive organs or of any bud, is now replaced with the modern conclusion that "formative" material as such has no actual existence and no good basis in theory. The present trend of thought leads to the assumption that growth proceeds from and depends upon states, or combinations, or accumulations in connection with living matter rather than any ineffable differentiated stuff or substance.

The second aspect of the subject was that which deals with the incorporation of new material in the cell and its subsequent distention. The protoplast is currently dealt with as a tonoplast, the center and seat of energy in this connection being the vacuole, while an indispensable organ in this conception of the cell is an ideal "semipermeable" membrane, acting on the basis of the fundamental researches of Pfeffer and de Vries.

The third group of inquiries has been directed toward measurements for the purpose of establishing the physical constants of growth.

The subject has been mistakenly dealt with as a unified process, or as a series of successive reactions in studies of temperature effects, with the result that the student now has available coefficients of doubtful value within not more than a third of the range of ordinary plants.

The chief defect in all three groups of research consists in the neglect of the fact that the metabolism upon which growth depends is a constellation, not a linear series of transformations, and that the most important part of the process lies within the realm of surface tensions in which the play of imbibition is the determining feature.

A further prerequisite to rational advance in researches on growth is a recognition of the fact that a general identity of protoplasm of plants and animals does not exist. The relative amounts of proteins, carbohydrates, lipins, and salts in two groups differ widely. In addition to the capacity of the plant to synthesize carbohydrates, amino-acids, etc., which the animal can not, the respiration and metabolism of the plant are predominantly carbohydrate, while those of the animal are proteinaceous.

The fundamental and ultimate structure or architecture of protoplasm is a result of the force of surface tension and is a gel in which the solid material occurs in two main states or phases with water. In the more liquid phase the molecules of the substance are associated with such a large proportion of water as to be in a liquid condition, while in the more solid phase the proportion of water is much less. These phases have a distinct architecture which has been likened to that of a mesh, felt, foam, or honeycomb in which the denser phase forms the framework and the fluid fills the interstices. Under certain conditions the phases may be reversed and the solid particles may be rounded into globules entirely surrounded by the fluid.

The essential feature of an idealized growth is the accretion or addition of water and material to the mass of colloid constituting the cell. The actual mechanism of incorporation is not easily delineated. The end-process is one, however, of hydration of a colloid, and it is upon this process that interest naturally centers in all studies of growth. The manner in which this takes place is one which may be most aptly designated as molecular imbibition, although it is not so simple as to be adequately and inclusively described by any single term. It is considered by some writers to be primarily absorption in which the entering liquid passes between the fibers of the spongy structure or honeycomb plates of the protoplasmic gel as it would into a layer of fine lamellæ or a dense tangle of closely piled fibers.

In that type of growth in which carbohydrates or proteins are carried into the mass by water, it may be seen that the accumulation of the additional material in the more liquid phase would, by the action of surface tension, result in the aggregation of new masses of material. Such formation of additional elastic gel structure might

occur theoretically throughout the entire mass of the cell, but in actuality would be modified and controlled at every point by the factors which affect hydration. Aggregation of material in syneretic cavities may be taken to present possibilities of the formation of specialized protoplasmic masses or cell-organs or of secretions.

Many mistaken attempts have been made to bring the growth of organisms and the formation of crystals into the same series of phenomena and to establish their identity or continuity. The results of such efforts serve to bemuse the mystic, to divert the philosopher, and to furnish poetical conceptions to writers who view matter and all material conceptions from a remote distance. The properties of compounds in crystalline form and of matter in a colloidal condition are so wide apart that no serious purpose is accomplished by the extension of terms to apply to the physical reactions of the two.

The Growth Mechanism of Protoplasm, by D. T. MacDougal.

Adequate experimental studies organized on the basis of data obtained by numerous analyses have established the fact that protoplasm of plants consists of a comparatively inert base of pentosans, which may be diffused or transformed only at a very slow rate, in colloidal combination with proteins, amino-acids, lipins, and salts to form a complex mass varying from the liquid condition to that of an elastic gel. The volume and changes in volume constituting growth will be determined by the proportion of water which may be taken up, and this is a resultant of the proportions of the main constituents. Other soluble carbohydrates, including the hexoses, occur in the cell, but not in such concentrations as to affect the enlargement of the protoplasmic mass directly, but in the vacuoles they may exert an osmotic effect additive to that of the amino-acids which may accumulate in these cavities.

It is to the osmotic activity of these substances in the vacuoles that turgidity is due, and an important part in the maintenance of the rigidity of organs and other features is to be ascribed to these turgor stresses and tensions. The inadequacy of osmotic phenomena and of the conception of the semi-permeable membrane to provide a mechanism for the translocation of complex material from cell to cell and the incorporation of new material in a growing mass has long been recognized. That osmotic pressure, however, may play an important part in the enlargement of the plant-cell may well be concluded from the fact that in the stage following the initial swelling of the embryonic cell a large share of the increase in volume is due to the increase of the vacuole. It would be a mistake to conclude that the vacuole is a sac charged with electrolytes only, as these cavities invariably hold proteins and carbohydrates in a colloidal condition in which the degree

of dispersion may vary widely, but still absorb water. This picture of the cell expanding by the osmotic action of electrolytes in the liquids and by the swelling resulting from imbibition or hydration of its colloids would not be complete without some delineation of the effect of the increasing changes within its mass.

Nowhere is metabolism more active than in the embryonic growing cell. The dissociations which are usually included in the conception of respiration may be taken to concern molecules of material, already present in the more liquid phase of the colloid or newly introduced. The splitting of the sugars results in the formation of acids as one stage of the process, and if the succeeding stages are impeded such material accumulates and acidosis results, with new temperature relations which may profoundly affect imbibition and the enlargement constituting growth. These changes exemplify but do not exhaust the possibilities of modifications of the colloidal action in growth.

The Nature and Course of Growth in Higher Plants, by D. T. MacDougal.

The development and standardization of the auxograph, which has been one of the principal instruments of research in these laboratories during the last few years, have made it possible to make measurements of changes in volume of organs of diverse origin and presenting different anatomical conditions. It has become evident, as a result of the comprehensive series of observations thus made available, that much of the present confusion as to the main features of growth arises from the fact that attempts have been made to compare and harmonize growth in organisms presenting physical conditions not really comparable.

Thus the growth of bacteria consists in the enlargement to a unit size of cells which become independent upon maturity, while growth in the higher complex plants entails the multiplication of embryonic cells and the development of the greater number of them into special static tissues to which the growing cells remain attached. An instrument applied to the terminal or growing portion of a higher plant thus records the changes in volume not only of the newest and youngest embryonic cells, but also of other tracts in all series approaching maturity. The implied distinctions and corrections must be made in any general discussion of the physical features of growth.

During the past year measurements under controlled and calibrated conditions have been made of the growth of such organs as the succulent leaves of *Mesembryanthemum*, the rapidly growing stems of the sunflower (*Helianthus*), pods of the bean (*Phaseolus*), and fruits of the potato (*Solanum*). The data obtained in this manner furnish a basis for the generalization that organs or members, when in a young condition and consisting entirely of embryonic

cell-masses, show a relatively rapid rate of enlargement by increase in length or in thickness. As maturity is approached, however, material subject to the ordinary out-of-door condition displays a lessened growth at midday or under certain conditions indicative of the fact that growth consists very largely of the imbibition of water and that water is also being lost from the surfaces of the growing members. So long as the amount of water taken up by the cell-colloids of the organ is in excess of that transpired by its surface, an enlargement ensues. If, however, at any time of the day or under any conditions the transpiration exceeds absorption, cessation of growth and actual shrinkage are inevitable. Such occurrences of lessened volume are illustrated by scores of records now on file.

In addition to shrinkages being caused by a deficit of water or of a loss exceeding the supply, there are also other changes, the physical nature of which is not obvious without an analysis of the conditions existing within the tissues. Among these conditions is the matter of acidity. It has been found that the colloids or cells of some plants are capable of imbibing or holding less water at temperatures of 25° to 30° C. than at 15° to 20° C. Consequently, when the temperature of such plants rises an actual contraction ensues which is not to be identified with any "optimum" or maximum.

Shrinkages or decrease in volume become more marked as maturity is approached. As a consequence there exists a state of affairs in a growing sunflower stem by which the extreme terminal portion will be found in a condition of continuous enlargement, the internode below will show daily shrinkages or cessation of growth in thickness as measured by an auxograph arranged for that purpose, while the internodes below will show even greater variations in volume. The older parts of the stem consist very largely of mature tissues which take up and give off water in a manner entirely reversible, and in organs or members in which the embryonic tissue is reduced to a minimum the widest range of reversible alterations occurs.

The estimation of the balance between water-loss and water-supply implied above has given a new and more important meaning to relative humidity as affecting growth.

The Dendrograph: A New Instrument for recording Growth and Other Variations in the Dimensions of Trees, by D. T. MacDougal.

The studies in growth which have received such a large share of attention in these laboratories during the last few years have been extended to include observations on a wide variety of material, in order to test the validity of the general principles which are taking form as a result of this work. Simple adaptations of the auxograph, mentioned in previous reports and described in detail in various papers,

have been adequate for the measurement of changes in volume of stems, leaves, nuts, fleshy fruits, etc. It has been necessary, however, to perfect a separate design for attachment to the trunks of trees in order to record daily and seasonal changes in diameter and form. Two successful types of such an apparatus have now been in operation at the Coastal Laboratory for two months. Both types employ a belt of wooden blocks 6 by 4 by 4 inches hinged together and fastened securely as a supporting belt around the trunk of a tree. In one type series of plungers in contact with a number of selected points around the tree carry on their outer ends an encircling wire. Any change in position of the plunger moves the encircling wire and the motion is recorded by a pen on a suitable revolving drum. The second type of dendrograph carries a yoke which encircles the trunk of the tree with four points of contact. Changes in volume of the trunk are followed by differences in distances between the contacts, which are duly recorded as above. At present these instruments have been used to obtain measurements from the oak (*Quercus agrifolia*) and the Monterey pine (*Pinus radiata*).

PHOTOSYNTHESIS AND METABOLISM.

Photosynthesis and Respiration, by H. A. Spoehr and Frances Long.

It has become evident that further insight into the complex phenomenon of photosynthesis is to be gained only by means of intensive study of the process under very carefully controlled external conditions and the elimination of secondary factors. For these purposes simple, thin leaves have proved to be the best material. By careful manipulation the mature leaf, isolated from the plant, can be worked with for several days without conflicting or deleterious reactions setting in.

After extensive preliminary experimentation, a rather elaborate apparatus has been devised and constructed for the accurate control of the conditions of temperature, light, air-supply, and water-vapor. The method now in use is based upon the differential determination of the amount of carbon dioxide fixed by the plant. For this purpose special apparatus has been devised for making exceedingly careful determinations of carbon dioxide by means of absorption in barium hydroxide. The solutions are titrated in an atmosphere free of carbon dioxide. The leaf is contained in a special glass cell provided with tubes for gas inlet and removal, as well as for the supply of nutrient solutions.

The features of the general problem which are now under investigation are rather manifold, though all are closely coordinated and interdependent. These comprise a study of the course of what might be termed the basic metabolism of mature leaves and the influence

of this metabolism and of the varying sugar-content of the leaf on photosynthesis. The rôle in respiration and photosynthesis of the proteins, amines, and amino-acids is being studied in the light of their regulatory and catalytic properties as components of protoplasm. And finally, the effect of the inorganic nutrients on photosynthesis is being investigated with a view of gaining some light on the rôle of these substances and establishing a rational basis for the use of mineral salts in relation to respiration and photosynthesis.

It has become evident that enormous differences exist in the leaves of different species as to the rate of carbohydrate elaboration and consumption. For example, leaves of *Helianthus* and *Phaseolus*, which with the comparative method of the iodine test show about the same rate of starch formation and consumption, when more carefully examined exhibit great differences. The former is about ten times more active than the latter, both as to respiration and as to photosynthetic activity. In general, it would seem that these two processes run at parallel rates, *i. e.*, plants which form carbohydrates rapidly also show a high rate of depletion of stored material. In the cacti and other plants rich in carbohydrates it has already been found that an increase in carbohydrates above certain limits does not result in increased carbon-dioxide evolution. Similarly, with decreasing carbohydrate supply, the rate of carbon-dioxide emission reaches a lower limit, below which it falls only very slowly.

From the results so far obtained it appears that the rate of photosynthesis is also closely related to the sugar-content and to the respiratory activity of the leaf.

A leaf in which the carbohydrate supply has been greatly depleted, when first exposed to light, exhibits a low rate of carbon-dioxide fixation. With continued illumination this rate increases decidedly, as does also the rate of carbon-dioxide elimination in the dark. As photosynthesis progresses and the leaf accumulates an abundance of carbohydrates, the rate of carbon-dioxide fixation again decreases. The latter observation is quite in accord with the results of Saposnikow, who demonstrated the reduced rate of carbohydrate formation as these substances accumulate in the leaf.

The Carbohydrate Economy of Cacti, by H. A. Spoehr.

The carbohydrate economy has been followed through a third year, and the seasonal variations analyzed in the light of climatic factors. As a final series of analysis, the past year was of especial interest on account of the rather extreme conditions which prevailed. There was very little rainfall during the autumn and winter. The effect upon the carbohydrates of the cacti of these conditions, together with the relatively low temperatures of the early winter, was very instructive.

As was previously established, low water-content of the plants results in a condition of general reversion of the carbohydrates to polysaccharides, while low temperatures result in a general inversion to monosaccharides. The continued dry weather kept the monosaccharide content unusually low for that season, until the cold nights of the late winter months effected a change, in that in spite of the low water-content the monosaccharides rose, and finally the late winter rains brought conditions of the carbohydrate equilibrium about to normal. It would seem that the water requirements of the cacti are easily satisfied, as in spite of the fact that the winter rainfall was very light, the water-content of the plants thereafter was about the same as during the same season of normal precipitation.

Special experiments on the effect of water-content and temperature on the carbohydrate equilibrium were repeated under improved conditions. The results obtained have substantiated and somewhat elaborated the former findings, which were given in the report of last year.

An effort has been made to coordinate the results obtained on the rate of respiration with the carbohydrate economy and the conditions influencing it. No simple or constant relation exists between the rate of carbon-dioxide elimination and the supply of carbohydrates; at least no method has been found of calculating the values obtained which permits of any such interpretation. Nor can the rate of respiration be constantly or definitely associated with any one group of carbohydrates. It has been commonly assumed that the monosaccharides or disaccharides play this rôle. However, it has been found that the content of the plant of the sugars may reach a point where a further increase is without effect upon the rate of respiration, while also a decrease in the content of these sugars below a certain point does not result in diminished carbon-dioxide emission. The limits of the range of content of these sugars which directly influence respiration are not fixed, but undoubtedly represent a combination of conditions intimately associated with a complex in which the protein-content and certain enzymes are controlling factors.

These considerations are of particular interest in the carbohydrate economy of the cacti in that under natural conditions the monosaccharides and disaccharides are present at times only in very small amounts. In spite of this condition, the rate of respiration does not show any marked diminution. It would seem, therefore, that under stress the plant possesses the power of utilizing the polysaccharides and aplastic material. An indication of this was already obtained by MacDougal, Long, and Brown in the study of cacti which had been starved for a long time.

The formation of pentosans is intimately associated with this condition. As has been previously reported, the simpler sugars, or monosaccharides, decrease in amount in the plants as the water-

content is reduced and, vice versa, an increase in water-supply results in a relative increase in these sugars. Pentosan formation is also dependent upon the water-content of the plant. With continued low water-content the pentosans increase decidedly, whereas an ample supply of water results in the reduction of the amount of pentosans. In the aldose monosaccharides the first carbon atom, or the carbonyl group (CH:O), is the most reactive and is largely responsible for the great reactivity of these sugars. In the disaccharides and polysaccharides found in these plants this active carbonyl group is so united with other groups that it no longer forms the point of attack in chemical reaction. These sugars are therefore first affected on the opposite end of the chain of carbon atoms, at the CH_2OH group. Such a reaction results in a primary formation of glucuronic acid, $\text{CH:O} \cdot (\text{CH.OH})_4\text{COOH}$. This substance has been found as a product of carbohydrate metabolism in animals, usually in the conjugated form. It has now also been found in the extract of the cacti, though only in very small amounts. Its presence is especially significant in that it indicates the mode of pentose formation in these plants. A very general property of acids of this character is the loss of CO_2 in the sunlight, and conversion into the corresponding lower aldehyde. In this manner glucuronic acid would form l-xylose. Neuberg (*Ergebnisse d. Physiol.* 3: 373, 1904) has actually obtained l-xylose from glucuronic acid by bacteriological methods.

Further evidence in favor of this interpretation of the formation of pentoses is obtained from the consideration of the structural relations of the various sugars concerned. If the pentoses were derived from the direct oxidation of the hexoses, d-glucose would yield d-arabinose, and d-galactose would give d-lyxose. It is a striking fact, however, that d-glucose has almost always been found together with l-xylose, and d-galactose associated with l-arabinose. This is precisely what would be demanded by the theory of the intermediate formation of glucuronic acid. Final evidence will be obtained from a study of the photolysis of glucuronic acid and other hexonic acids which is now under way.

Gas Interchange in Mesembryanthemum and Other Succulents,
by H. M. Richards.

Work was continued on the gas interchange and acidity of the species of *Mesembryanthemum* and *Dudleya*, which are native in the region around Carmel, California. In their natural habitat these forms do not, owing to the equable climatic conditions, show a very striking periodicity; nevertheless, even when the acid content is relatively stationary, the ratio of carbon dioxide evolved to oxygen absorbed is very low. To account for this is the problem at hand

It seems not unlikely that considerable quantities of carbon dioxide are dissolved in or in some way occluded by the fleshy tissue. A determination of the CO_2 content of such tissue under varying conditions is in progress. It is evident that the processes involved are at least somewhat dissimilar from those presented by the succulent tissue of the cacti.

The gas samples taken this year were preserved, as before, for later precision analysis, but during the progress of the experiments proximate analyses were made by a simple method that gave results accurate perhaps to 0.25 per cent. These supported the results previously obtained, but must of course be checked up by more careful determinations.

A considerable number of series of determinations were made of the acidities in leaves of different degrees of maturity. In the case of the terminal buds of the two common forms of *Mesembryanthemum* found at Carmel, there are at the tip usually two small leaves, while those immediately below are practically full-grown. It was found that the total acidity of the small terminal leaves was 1.20 c.c. N/20 KOH per gram fresh weight, while in the older leaves immediately below and the others farther back the total acid content was 0.60 c.c. N/20 KOH.

Similarly, in *Dudleya farinosa* the youngest leaves in the center of a rosette showed a total acidity of 3.00 c.c. N/20 KOH per gram fresh weight, while in the fully mature leaves the acid-content was only 2.25 c.c. N/20 KOH per gram fresh weight. The intermediate leaves showed, with some variation, intermediate acidities. That such should be the case is not surprising and is entirely consistent with the results obtained by Dr. D. T. MacDougal in his swelling measurements, but as far as the present work is concerned it indicates that for like results it is important to select tissues of like acidity.

Acidity of Mesophytic and Succulent Forms of Castilleja, Ericameria, and Erigeron, by H. M. Richards.

Some interesting forms of variation in degree of succulence of certain of the plants which grow on the foreshore and edge of the beach were found and their acidities and relative dry weight were determined. Thus in *Ericameria ericoides*, a common shrub near the sea-front, the foliage of the typical form is dark green and the linear-terete slightly hirsute leaves average 4 to 6 mm. long by 0.5 mm. thick, while a form growing on the cliff-edge overhanging the beach is yellowish green in color, with more glabrous leaves that are from 2.5 to 3.8 mm. long by 0.75 mm. in thickness. The total acidity and dry weight per gram fresh substance of the typical form are 2.70 c.c. N/20 KOH and 0.35 gram, respectively, while in the succulent type the total acidity is only 1.30 c.c. N/20 KOH and the dry weight

0.25 gram per gram fresh material. Thus the succulent form is strikingly less acid than the normal type.

In *Castilleja latifolia* two similar forms were also found even more striking. As this was the subject of more extended experimentation which will be reported elsewhere (see p. 85), only brief mention of it need be made here. In general, after making allowance for the difference in leaf-form and so forth, the same morphological differences were observed between the two forms as in the case of *Ericameria*. The succulent type is much lighter in color, less hairy, though rather more viscid than the typical form, and the thickness of the leaves is about twice that of the normal. The acidity also is about half as great in the succulent form, being 0.60 c.c. N/20 KOH per gram fresh weight, while in the thin-leaved type it is 1.50 c.c. N/20 KOH for the same weight. Observation of the distribution of the two forms indicated that the difference in growth habit was referable to water-supply. The cliff-edge, to which the succulent type is narrowly limited, is dry; further back the water-supply of the host on which *Castilleja* grows must be better. This was strikingly shown by specimens of thin-leaved type collected at the base of the cliff on the edge of the sand, actually in closer contact with the so-called halophytic environment of the true beach plants, but in this case copiously irrigated by the seepage at the base of the beach cliff.

Two forms apparently referable to *Erigeron glaucus* were also found, one on high cliffs overlooking the sea where the soil is very shallow, the other the common type found everywhere near the sea-front. The former was more succulent, the leaves measuring 0.60 mm. in thickness, and in this case more hirsute than the typical form. The thickness of the leaves in the latter case, which are merely finely puberulent, was 0.45 mm. The acidity of the more succulent form was 0.75 c.c. N/20 KOH per gram fresh weight, while in the thinner-leaved type the acid-content for the same fresh weight was 1.15 c.c. N/20 KOH. The difference in acidity is less striking here than in the other two cases cited.

In all these forms the succulent type is less acid than the normal form. Of course, when the acidity is reduced to terms of dry weight the relative acidities are more nearly equalized, but even then there is a disparity in favor of the *less* succulent tissue, which is more acid. This circumstance, while not in accord with some of our usually assumed characteristics of succulence, is of considerable interest. It will be remembered that in investigations of succulents we commonly do not have such strikingly different forms to compare. In cacti, other things being equal, it is true that the more desiccated tissue is the highest in acidity, but in these cases the comparative difference in succulence is not so striking as in the cases cited. No doubt more careful search would show other species of plants with such physiological variations.

IMBIBITION AND WATER-RELATIONS OF PLANTS.

Effect of Bog and Swamp Waters on Plants and on Biocolloids,
by D. T. MacDougal.

Hitherto it has been impossible to establish an adequate causal connection between the main physico-chemical features of bog and swamp water and their effects on plants, except that Clements has recently demonstrated that the lack of dissolved oxygen in the water of sphagnum bogs may account for its retarding action on growth and development. The composition of water from a sphagnum bog near Ronalds, Washington, as determined by Dr. J. M. McGee, included the following constituents per liter: Soluble organic matter 0.106 gm., ash (chiefly CaSO_4) 0.048 gm., total soluble residue 0.154 gm.; reaction neutral.

A similar sample from a sedge swamp near Anoka, Minnesota, gave the following per liter: Soluble organic matter 0.094 gm., ash (CaSO_4 with trace of NaCl) 0.128 gm., total soluble residue 0.222 gm.; reaction neutral.

The principal difference between the waters of the two habitats is that of the calcium sulphate in the swamp-water. The vegetation of the two places is of course quite dissimilar.

When a test was made as to the direct action of the water on sections of living plants and on plates of biocolloids the following hydration expansions were obtained for *Opuntia discata* (at 15° C.): Distilled water 18.2 per cent, bog water 18.3 per cent, swamp water 13.6 per cent, calcium nitrate 15.5 per cent.

The calcium-nitrate solution is of the concentration in which this salt enters into nutrient solutions.

Dried median slices of this plant gave swellings as follows: Distilled water 660 per cent, bog water 640 per cent, swamp water 530 per cent, calcium nitrate 625 per cent.

The nutrient solution used in all of these tests included four salts as follows: Potassium nitrate 1 M., di-potassic phosphate 2.38 M., magnesium sulphate 2.97 M., and calcium nitrate 2.95 M.

Attention was now turned to the biocolloids, to ascertain whether the action of plant material living and dried would find a parallel in the action of mixtures of known composition. Sections of plates composed of agar (90) and oat protein (10) were found to show the following swellings at 15° C.: Distilled water 1,928 per cent, sphagnum water 2,082.5 per cent, sphagnum water (neutralized) 2,228 per cent, bog water 1,200 per cent.

The degree of acidity of the sphagnum-bog water was such that 1.1 c.c. of N/10 potassium hydrate was necessary to neutralize 100 c.c. of water. The acidity of the grass-sedge water was scarcely a third of this, but 0.35 c.c. N/10 potassium hydrate being necessary to neutralize 100 c.c.

The biocolloid approaches more nearly to the condition of the protoplast, however, when in common with all living matter it includes some salts. The above mixture treated with nutrient salts was not available, but some plates in which the oat-protein was replaced by bean-protein (to which had been added 0.8 per cent of nutrient salts) were swelled in a parallel series at 15° C. with results as follows: Distilled water 1,417 per cent, bog water 1,444 per cent, calcium sulphate 0.048 gram. per liter 1,417 per cent, swamp water 944 per cent, calcium sulphate 0.128 gram per liter 1,083 per cent.

Bog water and an equivalent calcium solution allow equal swelling, but the increase in swamp water is much less and also less than in the equivalent calcium solution, to which may be attributed most of the retarding effect of the swamp-water derivatives. The swelling of biocolloids and of living and dried sections of plants in distilled water, bog water, and in a calcium solution of the same concentration as the bog water are practically parallel. So far as known to the writer, the effects of bog water are not attributable to any of its known constituents, and its low oxygen-content as tested by Clements may be responsible for its morphogenic and physiologic effects and its domination as a factor in the habitat.

Swamp water has been found to affect absorption and swelling in the same manner as an equivalent solution of calcium sulphate. Swelling and absorption are retarded by swamp water in salted biocolloids and in sections of plants containing a large proportion of pentosans and a low protein content. Biocolloids with a high protein and salt content, on the other hand, show an enhanced absorption in swamp water. Inferentially, plants of similar constitution would carry on absorption readily and thrive in swamp waters. Whether adaptation to swamp habitats actually takes this course is not known.

Colloidal Phenomena in the Protoplasm of Pollen Tubes: The Effect of Potassium and Sodium on Hydration and Growth, by Francis E. Lloyd.

In continuation of previous work reported upon in 1916 and 1917, attention was directed this year to the comparative effects of sodium and potassium in the form of hydrate. The hydration capacity of the protoplasm of the pollen of *Phaseolus* is increased by both hydrates, but more by potassium than by sodium in equal concentrations, viz, in N/3200 and N/6400, over that for water with 20 or 25 per cent cane sugar, the same concentration of sugar being present in combination with the hydrates, the temperatures being the same for all.

This increased hydration capacity expresses itself partly in swelling in excess of that available for growth and partly in the amount of growth. In the former case the pollen tubes burst before reaching their maximum growth; in the latter case the amount of growth in sodium is greater than that in potassium, and in the latter greater

than in the control. This difference in growth rates may be observable in the earlier phase only in the case of potassium.

It would seem that the potassium is absorbed more vigorously than is sodium by the protoplasm or by some element in the colloidal complex at present regarded as protoplasm. A toxic effect also is more obvious in the case of potassium. The observations have bearing on the comparative physiological effects of these two metals.

Temperature and the Hydration and Growth of Colloids and of Cell-Masses,
by D. T. MacDougal.

Recognition of the complex character of the groups of reactions which enter into the more prominent life-processes has brought conviction as to the futility of attempts to define physical constants, such as temperature coefficients. For example, variation in temperature results in modification of the rate of enzymotic processes and of the forms of metabolism included under and associated with respiration; modification of the rate of absorption of water by the organisms from its medium or substratum; modification of the water-holding capacity of the cell-colloids after a mode determined by their carbohydrate protein ratio and by the state of acidosis. The actual increase in volume will also be influenced to some extent by the water-loss which takes place.

A determination of the effect which temperature might have on growth necessarily takes into account first the fundamental increase which might accrue from simple absorption under various conditions. In recognition of this fact, it was arranged to carry on swellings of some of the biocolloids in order to gain some appreciation of the imbibition factor in growth. Sections (2 mm. in thickness) of plates of agar and of agar 90, bean protein 10, and nutrient salts 0.85 per cent, were swelled at temperatures of 15° C. to 49° C. in a constant-temperature room. The differentiated effects are illustrated by the following set of measurements:

The hydration reactions of the agar are not so positive and uniform as those of the biocolloids. Increase by absorption had not reached a positive final in 24 hours at the lowest temperature. A similar stage of satisfaction was evident in half this time at about 40° C. and in 8 hours at 49° C. The maximum or "optimum" of swelling of such agar plates occurs at some temperature near 40° C. Initial rate and total increase are greatest at this point.

The agar-oat protein mixture has a higher maximum initial capacity at 46° to 47° C., but does not appear to absorb as much water as at a temperature a few degrees lower. The maximum swelling of the agar-bean protein and salt mixture lies below 46° C. and is probably

Swelling of agar.

Temp.	4 hrs.	8 hrs.	10 hrs.	12 hrs.	16 hrs.	20 hrs.	24 hrs.
°C.							
18-21.....	875	961	.....	1069	1111	.....	1153
	806	889	.....	1000	1054	.....	1083
	944	1083	.....	1139	1168	.....	1222
27.....	1000	1083	.....	1278	1333	.....	.....
	1056	1167	.....	1208	1250	.....	.....
29-31.....	1292	1389	.....	1417	1444	.....	.....
39-41.....	1472	1556	.....	1583	.....	.....	.....
	1750	1778	.....	1833	.....	.....	.....
40-41.....	1611	1667	.....	.....	.....	1708	.....
46-47.....	1306	1389	1416	.....	.....	.....	.....
48-49.....	1333	1417	.....	.....	.....	.....	.....
Averages.							
18-21.....	875	978	.....	1069	1111	.....	1153
27.....	1028	1125	.....	1244	1222	.....	.....
39-41.....	1611	1667	.....	1708	.....	.....	.....
46-49.....	1320	1403	1416	.....	.....	.....	.....

Agar 90, oat protein 10.

Temp.		4 hrs.	8 hrs.	20-22 hrs. (final).
°C.		<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>
15-16.....	0.18 mm.	1167	1459	1794
22-23.....	0.18 mm.	1388	1550	1900
30-31.....	0.16 mm.	2172	2763	3078
38-39.....	0.18 mm.	2541.6	2861	2917 (12 hrs.)
46-47.....	0.18 mm.	2555.5	2833.1	2889 (10 hrs.)
48-49.....	0.16 mm.	1906.3	2031	Complete.

Agar 90, bean protein 10, nutrient salts 0.85.

Temp.		4 hrs.	8 hrs.	20-22 hrs. (final).
°C.		<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>
15-16.....	0.20 mm.	888	1113	1325
21-23.....	0.20 mm.	1388	1550	1900
30-31.....	0.18 mm.	1472	1735	2022
39.....	0.18 mm.	2486.1	2736	2791 (12 hrs.)
46-47.....	0.18 mm.	2153	2347	2361 (10 hrs.)
48-49.....	0.18 mm.	2361	2514	Complete.

above 40° C., as both speed and total capacity become uncertain at 46° C. and above. All of these critical points lie within the range of activities of plants.

Perhaps the most striking example of diverse and contradictory effects of a single agency is that of rising temperature on the swelling

and growth of acid cell-masses. The petioles of some young plants of a *Solanum* hybrid in the glass house at Tuscon were available on April 21, 1918. Trios of sections were placed in distilled water and acids at 18° to 38° C., with results as follows:

Temp.	Distilled water.	Hundredth normal citric acid.
	<i>p. ct.</i>	<i>p. ct.</i>
18° C.	4.2	4.2
38° C.	11.8	2.6

The swelling in distilled water was nearly three times as great at the higher temperature, while in the acid solution a retardation took place which limited the total at the higher temperature to something over a half that possible at the lower point. The total swelling in acid at the lower temperature occupied an hour and at the higher temperature it was a matter of 10 or 15 minutes. A similar speeding-up of imbibition in water was observed. The total capacity at the lower temperature was not reached for 8 or 10 hours, while at the higher it was something under 2 hours.

A second test of variations in temperature upon material in an acidified condition was made with dried sections of *Opuntia* 0.43 to 0.46 mm. in thickness, which gave the following:

Temp.	Distilled water.	Hundredth normal citric acid.
	<i>p. ct.</i>	<i>p. ct.</i>
18° C. average..	395	417
28° C.	453	460
38° C. average..	457	439

The increase in swelling in distilled water is seen to be about twice that in the acid in the rise from 18° C. to 38° C. The influence which the condition in question may exert on the rate of growth is obvious. Thus the course of enlargement of an organ or of a cell-mass, in so far as this consists in hydration, may vary widely in the first instance because of the residual acids in the colloids, and the balance or accumulation of this will in turn depend upon the effect of the enzymatic or respiratory process in metabolism. A rise of 10° from the customary morning temperature of 15° C., which has been encountered in so many of these experiments, would result in an acceleration of growth largely determined by the state of acidosis of the plant. A rise from the same temperature later in the day or under other conditions of illumination would necessarily have a different result.

The Mucilage of Opuntia, Abutilon, and Oenothera, by Francis E. Lloyd.

The opuntias and mallows contain a mucilage having a very high hydration capacity, as is shown readily by placing pieces of tissue in water, when the material in question swells to form a ropy mass of high viscosity. It occurs in relatively large cells which arise by idiosyncrasis from parenchyma cells and only in minor extent from embryonic tissue. In *Opuntia* they are distributed in the medulla and in the cortex, in some species (*Opuntia discata*) coming very close to the hypodermis, and in others leaving a considerable zone of chlorenchyma free from them (*Opuntia blakeana*). When sections from such kinds are judiciously cut parallel to the epidermis and placed in water, no escaping mucilage may be detected. In *Abutilon* the mucoblasts occur chiefly in the stem, pericarp, and corolla. The structure of these cells is identical in both. The mucilage arises from the inner zone of the cell-wall. This, during the early development of the mucoblast, when it enlarges greatly, shows no chemical divergence until the mucilage begins to be formed, when it gives in its inner zone the hydro-cellulose reaction. The accumulation of mucilage, together with its hydration, results in the gradual contraction of the protoplast in the middle of the cell, its connection with the original cell-wall being frequently sustained by radiating strands which at their outer ends are attached to the pits connecting with adjacent cells. With age the protoplasm becomes disorganized and partially obliterated, there remaining only thread-like traces.

The adsorption capacity for staining colors (and other substances) is of peculiar interest. Here may be mentioned particularly two cases. Neutral red is adsorbed from a neutral or slightly acid, but not from an alkaline solution. The staining is not, however, selective, since it is also taken up by the cellulose, oil, annulæ of the xylem, etc. When partly hydrated mucilage is placed in stronger neutral red, the hydration is arrested and the color is adsorbed with extreme avidity. Ruthenium red (as little selective as neutral red) precipitates the mucilage and will, in the course of some days, render the mucilage *in situ* incapable of further swelling even in boiling water. The mucilage masses are then evidently coagulated and break under pressure in the manner of coagulated tannin masses, as described by the writer.

Many other stains are adsorbed feebly and with little or no coagulating effect, while still others not at all, and these have no effect on the hydration capacity of the mucilage.

When the tissues are dehydrated, as by alcohol, the mucilage masses undergo internal syneresis, minute cavities occurring in more or less regular zones alternating with homogeneous zones. This was found to be due to the different degrees of hydration of these zones, corresponding to a laminated structure, seen by Longo, resulting from the mode of origin of the mucilage. On the addition of water, the

syneretic cavities disappear and the laminated structure appears in its place.

In the living tissues the mucilage masses and the surrounding parenchyma cells are in unstable equilibrium, the hydration capacity of the mucilage being great enough to withdraw more or less water from the adjacent cells. When water is allowed access to the tissues, some mucilage cells may burst. The same result may be obtained by causing the loss of water from the parenchyma by asphyxiation.

The rather abundant mucilage of *Oenothera* occurs within the protoplasmic utricle (in contradistinction to the foregoing forms) in elongated fusiform cells which are raphid idioblasts. It also is precipitated *in situ* by ruthenium red, the whole becoming flocculated and undergoing syneresis to form a nematoid mass. When exposed to neutral red (acid solution) the stain is first adsorbed in the interior of the mucilage in the neighborhood of the raphids, the affected volume then extending radially in all directions. At first the adsorption complex usually occurs in the form of interwoven threads of very minute caliber, which, with thickening, ultimately form a flocculent mass. Both stains slowly render the mucilage insoluble.

The Colloidal Properties of Certain Plant Mucilages as affected by Stains,
by Francis E. Lloyd.

The writer has often observed that when substances such as the mucilaginous products of the hydrolysis of cellulose walls which occur during abscission, the ripening of fruits, etc., are treated with certain staining materials, a quasi precipitation occurs. Recently it was found that ruthenium red causes the formation of insoluble membranes on the surface of *Opuntia* mucilage. Following this lead the effects of a considerable series of dye materials on the mucilage of *Opuntia*, *Abutilon*, *Oenothera*, peach pericarp, and the products of cell-wall hydrolysis during abscission were studied.

It was found that some stains (*e. g.*, neutral red, ruthenium red) slowly reduce the viscosity of hydrated mucilages until their physical properties as emulsion colloids entirely disappear. These stains are adsorbed with great vigor. On the other hand, some stains (*e. g.*, corallin, methyl orange) are not adsorbed at all and have no effect on the viscosity or hydration capacity of the mucilage. Still other stains (*e. g.*, methylene blue) are slightly adsorbed and at the same time measurably reduce the viscosity. In general it may be said that the viscosity of the mucilages in question is reduced by stains in direct relation to the adsorption capacity of the mucilages for these stains.

The Index of Transpiring Power of Plants, by Edith B. Shreve.

As mentioned in last year's report,* the chance for the greatest error in the use of the tripartite cobalt-paper slips for determining the in-

* C arnegie Inst. Wash. Year Book for 1917, p. 68.

index of transpiring power rests in the assumption that the slips are at the temperature of the surrounding air. The type of thermo-couple described in another section (page 80) has been adapted to test the temperature of the cobalt paper as it rests upon the leaf under its glass cover. Tests have been made on widely different types of plants, growing both in the greenhouse and in the open. In all cases the temperatures were read every 10 seconds until the cobalt test was completed. While the temperature of the leaf-surface itself frequently differs several degrees from that of the surrounding air, the temperature of the cobalt slip covered by glass does not reach so great a difference during the time required for a cobalt test. The temperature of the slip departs from the air temperature by different amounts, according to the time of day, the season, the amount of cloudiness present, the conditions of the plants, etc., the departure being from zero to 1.5 degrees. The last amount is for temperatures above 30° C. only.

Following is a list of plants for which the indices of transpiring power have been calculated,* using first, the temperatures as read from a shaded mercury thermometer standing in the foliage of the plant, and second, the temperature obtained by making a correction embodying the maximum difference from air temperature obtained for that plant for that time of day:

<i>Encelia farinosa</i> .	<i>Phaseolus</i> sp.	<i>Amaranthus palmeri</i> .
<i>Prosopis velutina</i> .	<i>Rumex hymenosepalus</i> .	<i>Bahia absinthifolia</i> .
<i>Fouquieria splendens</i> .	<i>Nasturtium</i> sp.	<i>Streptanthus arizonicus</i> .
<i>Lantana</i> sp.	<i>Ricinus officinale</i> .	<i>Malva borealis</i> .
<i>Poinsettia</i> sp.	<i>Tradescantia</i> sp.	

In no case does the second result differ from the first more than 8 per cent, and in the majority of cases it is under 2 per cent. The maximum difference between the indices of 10 different leaves of the same apparent age on the same plant is frequently over 20 per cent and never under 8 per cent. Consequently this work has established the fact that the temperature of the air may be safely used for the temperature of the cobalt slip.

It is of course just as important to know whether or not the air temperature may be safely used in the calculations for the standardization of the slips over a porous evaporating surface. With a slight change in the apparatus the temperatures of the slips as they rested over the standard evaporating surface were taken, the tests being made at 1° intervals between 20° and 30° C. The results show definitely that if the standardization is made within 2° or 3° of 20° C. the error introduced is smaller than that obtained from consecutive readings on the same slip at any given temperature. The above statement does not hold for temperatures above 24° C. All the

* For method, see Livingston, B. E., and E. B. Shreve, Improvements in the Method for Determining the Transpiring Power of Plant Surfaces by Hygrometric Paper. The Plant World, vol. 19, No. 10.

calculations have been based upon the ratios of maximum vapor pressures of water in the air at 20° C. to the corresponding pressures at other required temperatures; consequently, no inconvenience is caused, especially as it has already been proved that the tripartite slips may be standardized in the laboratory and used in the field months or years later.

Investigations on the Imbibition of Water by Gelatine, by Edith B. Shreve.

EFFECT OF INCLUDING VARIOUS SOLUTIONS WITHIN GELATINE JELLY.

It was noted in the report of last year* that when gelatine is soaked in M/2 and M/4 solutions of sodium sulphate, sodium citrate, or sodium tartrate for several hours, heated to 60° C., and then allowed to cool, the resulting jellies absorb distilled water at a faster rate than does a jelly of the same water-content made with distilled water. Hofmeister and others have shown that gelatine made with water alone absorbs water at a slower rate from these solutions than from distilled water. Since a number of workers in biology and in colloidal chemistry have drawn conclusions based on the assumption that the presence of a substance within a jelly has the same qualitative effect on its capacity for absorbing water as does the presence of the same substance in an external solution, it seemed advisable to test the matter more fully.

Stiff gelatine jellies were made as described above, using the following solutions instead of distilled water: M/2 and M/4 sodium sulphate; 2M, M, and M/2 sodium tartrate; 2M, M, and M/2 sodium citrate; 2M and M (approximate) ethyl alcohol; M and M/2 cane sugar; M sodium chloride; M ammonium chloride; M sodium bromide. The original water-content and the evaporational history of all jellies compared was always the same. With the exception of the one made with cane sugar, all of these jellies absorbed distilled water at a faster rate than did jellies made with water alone. This was found to be true also after the jellies had been evaporated to dryness.

It seemed possible that when the gelatine and salt solutions were heated to 60° C. a chemical change might have taken place which does not occur at the temperatures at which the imbibition experiments were carried on and that here might be an explanation of the difference in behavior when the salts are made up in the jelly and when they act in the surrounding solution. In order to introduce the salts into the jelly without heating them with the gelatine, the gelatine jelly was made with water in the usual way, and after setting it was allowed to absorb all of a small measured quantity of the solution whose presence was desired in the jelly. Then this jelly containing the solution was placed in distilled water. Again it was found that, with the exception of cane sugar, the jellies containing the substances

* Carnegie Inst. Wash. Year Book for 1917, p. 69.

given above absorbed water faster and took up a larger total of water than did the jelly made from water alone. Parallel tests to determine the rate at which gelatine jelly made with water alone absorbs these same solutions showed the usual results, namely, in the cases of sodium chloride, ammonium chloride, and sodium bromide the rate is faster than it is for water, and in the other cases slower than it is for water.

This work has shown, then, that it is not safe to draw conclusions regarding the effect which substances within a jelly exert upon its imbibitional capacity, when evidence for such a conclusion lies in the known effect of an external solution of the same substance on that jelly. This applies to the theories involving the physico-chemical effect of the substances upon the gelatine itself as well as those concerning physiological phenomena.

EFFECT OF HEAT ON IMBIBITION OF WATER BY GELATINE.

Some confusion exists in the literature regarding the effect of heat on the absorption of water by gelatine. It is claimed, for example, by Taylor that (according to le Chatelier's theorem) heat will hinder or diminish imbibition, while cold will increase it. The matter has been investigated in a series of tests made at 10°, 20°, and 32° C. The rates of absorption and the maximum water-content were obtained for 500 pieces of gelatine of various sizes, the gelatine being in various initial conditions of water-content. Invariably the higher the temperature the greater was the rate of imbibition and the larger the maximum water-content at the point of apparent equilibrium.

This theorem of le Chatelier is applicable only to equilibrium phenomena, and it is probable that gelatine and water do not reach a true equilibrium at ordinary temperatures. In a large number of attempts to find a true equilibrium no absolute maximum of water-content was found. As the maximum is approached, a very appreciable amount of gelatine passes from the surfaces of the pieces and becomes dispersed in the water. Whenever an apparent maximum was reached it could be increased by separating the pieces of gelatine into smaller fragments. Bacterial action prevented continuing any given experiment longer than 4 weeks at temperatures from 10° to 20° C. or 2 weeks at temperatures above 25° C. Consequently it was not possible to show that a piece of gelatine will become completely dispersed in water at the temperatures used. But the evidence all goes to show that at these temperatures gelatine takes up water to at least nearly unlimited amounts when given unlimited time. Certainly, there is no temperature between 10° and 30° C. where a true point of equilibrium is reached within less than 2 weeks. Since the rates of absorption closely approach a hyperbolic curve when plotted, it may be assumed that the equilibrium-point is never reached. It thus seems highly probable that le Chatelier's theorem is not applicable to the phenomena of imbibition of water by gelatine.

So far as biological phenomena and their interpretation are concerned, the apparent equilibria may usually be treated as real ones, because all important biological phenomena take place within a limited time; it is only when an attempt is made to predict from theoretical reasoning that caution must be observed in determining the presence of true equilibria.

Water Content and Abscission in the Nuts of Juglans californica quercina, by Francis E. Lloyd.

Individuals of this mutant bore numerous fruits in the garden this season. Usually three to five fruits were set on each peduncle, of which ultimately all but one, if not all, were shed. This behavior is analogous to the shedding of cotton bolls, of young oranges ("June drop"), etc., which has been shown to result in the main from disturbed water-relations in the plant. Through cooperation with Dr. D. T. MacDougal, who was making auxographic studies of the *Juglans* fruits, it was possible to obtain growth records of such as ultimately became separated from the twig by abscission.

An examination of a critical record shows that, previous to the abscission period, there was a net gain in dimensions of the fruit on each day, the amount of daily shrinkage being less than the amount of growth. The net daily growth was sensibly less on each successive day during the earlier period of observation of 8 days. For the subsequent 3 days previous to separation, however, the relation of growth to shrinkage was reversed, till on the final (eleventh) day, at the conclusion of which abscission was complete, there was observable only shrinkage, and this in marked amplitude.

Observations on the abscission period showed that the process occupies about 2 days in nuts as small as those measured auxographically. It may be soundly argued, therefore, that the inadequate supply of water to the growing nuts is the exciting cause of abscission.

The method of abscission is similar to that described by the writer for the cotton plant (*Gossypium*).

ECOLOGY.

The Vegetation of an Imperfectly Drained Desert Valley, by Forrest Shreve.

During the past year progress has been made in a study of the physiography and vegetation of the Avra Valley, an imperfectly drained desert basin lying west of Tucson. A drainage area of nearly 200 square miles is tributary to this valley, including the Baboquivari Valley, a portion of Santa Rosa Valley, and several minor areas. Although a number of intermittent waterways of considerable size empty into the Avra Valley, there is no central and permanent drainage from it into the Santa Cruz River, toward which the valley stretches with a falling gradient.

The central feature of the valley is an elongated floor from 10 to 20 miles in width, which is level from side to side and has an average fall of about 20 feet to the mile throughout its length. Surrounding the central floor is a more extensive area of bajada, and beyond this is an almost unbroken circle of mountains and hills. The drainage-ways which cross the bajadas are found to terminate at the edge of the central floor. Only in the case of the Baboquivari Valley does a tributary, nearly 50 miles in length, penetrate the central floor, for a distance of about 4 miles. Stream-ways are not absent in the floor of the valley, but they are of ephemeral character, and rarely exceed 4 feet in width and half a mile in length. There are no dry lakes.

The history of the valley is one of gradual filling and leveling in which the streams deposit their loads on reaching a gentler gradient and have insufficient volume to cut through their own deposits. From time to time, short temporary stream-ways are cut through these areas of deposition, only to be filled again by the development of small lateral drainages. The constant shifting of the regions of cutting and deposition is largely determined by the sporadic occurrence of torrential rains in different parts of the drainage basin.

The vegetation of the bajadas appears to be determined by the character of the soil. On the sands and light loams derived from granitic mountains there is a heavy cover of *Parkinsonia* and *Acacia*, while *Covillea* and *Carnegiea* are absent. On the heavier soils, with coarse rock fragments, derived from volcanic mountains, there is a light stand of *Covillea*, *Prosopis*, *Parkinsonia*, and *Carnegiea*; or at the base of such bajadas are frequently found pure stands of *Covillea*. The floor of the valley is occupied by three types of vegetation, which are not so obviously related to types of soil: (a) pure stands of *Covillea* near the edges or on very slightly elevated areas; (b) open or closed parks of *Prosopis* with a ground-cover of *Isocoma* and perennial or annual grasses; and (c) very open areas with isolated bushes of *Lycium* or *Atriplex*.

Covillea appears to occupy areas in which the soil-surface has long been stabilized, *Prosopis* the areas not recently subjected to change of level, and *Lycium* and *Atriplex* the areas that bear evidence of recent overflow or sheet-flood deposition.

Field and laboratory work has been inaugurated with a view to investigating the rôle played by the soil in determining the sharp differences of vegetation which characterize the Avra Valley. The vegetation has been mapped in detail for a representative portion of the valley, and the character of the soils is under investigation with respect to this area in particular. An opportunity is here afforded to determine whether different types of vegetation may exist under

identical physical conditions, or whether dissimilarities of soil texture and conditions of soil aeration are closely correlated with those of the plant covering. The fact that the Avra Valley is not undergoing the normal course of physiographic development, but is subject to frequent checks or reversals of such development, makes it a particularly suitable area for an investigation of this problem.

Geobotany of the Santa Lucia Mountains, by Forrest Shreve.

A reconnaissance has been made of the vegetation of the Santa Lucia Mountains, which skirt the coast of the Pacific Ocean between Monterey and San Luis Obispo, California. The physical conditions of the region are dominated by the rainless summer, which is characteristic of the entire Pacific Coast, and by the proximity of the sea.

The region is like many other Californian areas in having a very dissimilar series of vegetations growing in close proximity. Among these are: (a) grassland, embracing many annual and root-perennial plants; (b) open oak forest, usually superposed upon the grassland; (c) closed oak forest, with abundant shrubbery; (d) redwood forest, with characteristic accompanying trees and shrubs; (e) chaparral, varying greatly in composition and vegetative characteristics. The most xerophytic of these vegetations is the grassland, which is found in the valleys and on the detrital slopes and hills of the landward side of the mountains. In a number of localities it is found to dominate all situations without regard to topographic or soil differences. The most hygrophytic of the vegetations is the redwood forest, which occupies only the seaward valley-bottoms and slopes, usually where it is subject to frequent visitation by fog.

The chaparral varies in density, height, and composition, but in some one of its many forms it is the most ubiquitous of the vegetations. The most xerophytic forms of chaparral are composed solely of *Artemisia californica* or of *Salvia mellifera*, the former being commonest in the interior, the latter on the seaward slopes. *Adenostoma fasciculatum* forms the most abundant type of chaparral in all parts of the area, growing in pure stands more commonly than is true of the other chaparral shrubs. *Arctostaphylos* is dominant mainly on sandstone rock or sandy soil, or at high altitudes, often growing with *Ceanothus*. The most hygrophilous types of chaparral are those made up of species of *Ceanothus*, which usually reach a much greater height than the other chaparral plants. This type is frequently invaded by young oaks, *Umbellularia*, and *Arbutus*.

The conditions determining the occurrence of grassland and of redwood forest are rather obvious, but this is by no means true of the types of chaparral mentioned and of several other less common ones. Differences of elevation between sea-level and the highest peaks and

ridges play only a minor part in bringing about a differentiation of the chaparral. Differences of slope exposure may determine the presence of the composition of chaparral in all regions except the most arid interior hills, where there is none at all, and the hills facing immediately on the sea, where it is very uniform. Differences of slope gradient, with the accompanying differences of soil depth, frequently appear to condition the occurrence of chaparral, gentle slopes with deep soil being occupied by grassland, while the steeper or rocky slopes are covered by chaparral. Differences in the character of the soil have been found to accompany differences in the composition of the chaparral, but the significance of a given relation changes on going from the seaward to the landward side, and to some extent on going from lower to higher elevations. Chaparral is absent from the nearly level summits of many hills, even in close proximity to the sea, although the slopes of the same hills are covered and the similar summits of adjacent hills are also covered. At higher elevations the level summits are covered by chaparral, but the south and west slopes are often occupied by areas of grassland. Immediately south of Monterey the hills are covered with chaparral from the beach to their upper summits. From Cayucos to the mouth of San Carpophoro Creek the hills adjacent to the ocean are grass-clad and devoid of chaparral, except on steep, rocky, landward slopes. An elucidation of the many ecological problems presented by the chaparral will require much more extended and intensive work.

The Santa Lucia Mountain region embraces, chiefly or entirely, the distributional areas of *Pinus radiata*, *Abies venusta*, *Cupressus macrocarpa*, and *Cupressus goveniana*, as well as the southernmost localities of *Sequoia sempervirens* and a number of its associates. An examination has been made of the habitat characteristics of these plants, with particular reference to *Pinus radiata*. This tree is found only at the northern and southern extremities of the Santa Lucias, in spite of the existence of apparently favorable habitats in the intervening region. In the vicinity of Cambria and San Simeon it exhibits a greater catholicity of habitat requirements than in the vicinity of Monterey and less dependence upon proximity to the sea. While geomorphic movements undoubtedly lie at the basis of the present distributional features, there is offered, nevertheless, a fruitful problem for investigation with respect to the factors controlling the reproduction and life-histories of all these endemic forms.

A Soil-Temperature Survey of the United States and Canada, by Forrest Shreve.

In 1916 the Ecological Society of America appointed a committee consisting of Forrest Shreve, chairman, and Dr. Alfred E. Cameron, of the Dominion Entomological Service of Canada, charged with carrying out preliminary soil survey of the United States and Canada.

While numerous records of the temperature of the soil have been kept at various localities, they have largely been of such a nature as not to be comparable one with another. The work of this committee was inaugurated with the fundamental purpose of securing a series of soil-temperature data for a period of several years under conditions as nearly identical as possible. The aim has been to secure thermograph records from bulbs placed at the same depths, in level, well-drained soil, free from the shade of trees or buildings, and under a ground-surface kept free of sod or weeds, but without continuous cultivation. Very light and very heavy soils have been avoided, except in cases where no others were to be found in the vicinity of the stations. Marked differences of soil temperature are known to accompany differences of soil texture in the same locality, but it was deemed inadvisable to attempt to place all of the thermograph bulbs under identical soil conditions by transporting the same type of soil to all stations. Such readings would result in obtaining a series of physical constants that would have only an indirect relation to the natural vegetation and agricultural activities of the regions in which the various stations are located.

During 1917 over 30 stations were maintained by the valued cooperation of as many men, and nearly complete records for the year were secured at most of these stations. The distribution of the instruments is such that data are being obtained from all parts of the United States and from portions of Canada. At several stations bulbs are installed at 12 and at 3 inches, while at the majority of the stations they are maintained at 3 inches only. Still more intensive investigations of soil temperature are being carried out by several of the cooperators who were interested in the subject prior to the inauguration of the survey. It is hoped that the series may be maintained for several years and that it will then be possible to draw a map of the isotherms of soil temperature for northern North America. When this work, has been carried through with our knowledge of the temperature of the soil, it may be placed on a geographical basis, as has long ago been done for the temperature of the air and other conditions of critical importance to plant and animal life.

Apparatus for determining the Temperature of Leaves, by Edith B. Shreve.

A method for the determination of leaf temperature has now been brought to a stage where it can be used satisfactorily for finding the surface temperature of leaves without wounding them. The time required to obtain a given temperature is less than 10 seconds. The essential part of the apparatus is a thermo-couple made of No. 40 "Ideal" and copper wires, one junction of which is so fastened to a light spring clip that it is held in position on the surface of a leaf without shutting the leaf off from the influence of the surrounding

air. The other junction is placed in a small thermos-bottle with a mercury thermometer. A portable galvanometer (of sufficient sensitiveness to detect changes of temperature of less than 0.1° C.) and a damping-key complete the main parts of the apparatus. The various units are arranged on a board about 7 inches square, which can be screwed to a photographic tripod, and the whole can be easily moved about from plant to plant. The calibrations are made in the laboratory, so that in the field the swings of the galvanometer may be quickly translated into temperatures. The galvanometer is sensitive enough so that it makes no difference how near the temperature of the leaf the second junction may be, it being essential only that its temperature be known. Thus there is no need for ice or warmed water to be carried into the field. The second junction is placed in a thermos-bottle to avoid sudden changes in its temperature while the readings are being made.

The apparatus has been used to measure the temperature of the leaves of a large number of plants belonging to widely different ecological types and growing under very dissimilar conditions. Readings have been taken on both upper and lower surfaces and in all cases the leaves have been *in situ* on plants living in their natural habitats or in a greenhouse. The localities in which work has been done comprise the desert near Tucson, mountains in the vicinity of Tucson, and the Santa Lucia Mountains in California. The results have not yet been sufficiently assembled to warrant statements of the conclusions. The most outstanding fact is the rapidity with which the surface temperature of a leaf growing in the open may fluctuate within a time of 20 to 60 seconds, the change frequently amounting to from 1° to 3° C. Such fluctuations occur also in the air temperature, but are too rapid to be registered on a mercury thermometer. In the greenhouse these fluctuations do not ordinarily occur, either on the plant surfaces or in the air. Changes in atmospheric conditions are without doubt the cause of these fluctuations. If a moderately strong wind is blowing the temperature of the leaf-surface may change as much as 5° in 30 seconds.

Root-growth in Desert Plants and the Oxygen Supply of the Soil,
by W. A. Cannon.

In the root-soil aeration there are two features of much importance. One of these relates to the amount of carbon dioxide in the atmosphere of the soil, and the other to the supply of oxygen. In arable lands it appears that at the time of the greatest vegetative activity of soil organisms, of whatever kind, there may be a slight excess of the former and a small decreased amount of the latter. Neither the one nor the other, however, is in sufficient amount to materially affect root-growth. Although no direct quantitative determinations have

as yet been made of the CO_2/O_2 content of uncultivated soils in arid regions, there is reason for supposing that this may vary considerably from season to season, and especially in soils of different fineness. This conclusion rests in part on the known great differences in the texture of soils in the arid regions, and in part on differences in root-oxygen carbon-dioxide responses as exhibited by xerophytic perennials of unlike root-habits.

It is presumable that the surface soils in the arid regions during dry seasons are all adequately aerated, but this is not the case during the rainy seasons. The soils of finest texture—for example, adobe—become easily saturated with water and in the puddled condition free air-movement is impossible. Under the same conditions of rainfall the other and coarser soils either are not puddled, or if so, the saturated condition lasts for a relatively short time only. The importance of the distinction of soils according to their texture lies in the fact that in all soils, but significantly so in those of the finest texture, the season of greatest vegetative activity occurs in midsummer, when such soils are puddled. It therefore seems possible, owing to known slowness of movement of gases by diffusion only, that the oxygen-content of saturated soil at this time may be quickly and considerably lowered, while at the same time the amount of carbon dioxide may be noticeably increased. With the passing of the rainy season this condition of poor soil aeration would naturally cease.

Inadequate soil aeration works in two ways. The accumulation of carbon dioxide, through its known narcotic effect, operates to depress growth and also, as the amount of available oxygen becomes less, growth for this reason diminishes in intensity. It is probable that there is a specific response to parallel amounts of CO_2/O_2 in the soil, as shown by land plants of unlike root-habit, especially. It has already been shown (Carnegie Inst. Wash. Year Book No. 15, 1916) that excessive amounts of carbon dioxide are more toxic to roots of *Opuntia versicolor* than to roots of *Prosopis velutina*. Recent experiments have shown that the roots of these two species have an unlike relation to a diminished amount of oxygen in the soil air. This is indicated by the following summary. In these experiments parallel series of cultures were grown at constant temperatures and in soil. The summary gives the observed length of time in days that root-growth was seen to occur in the two species and growing under similar conditions:

Percentage of oxygen in the soil atmosphere.	Root growth in days.	
	Opuntia.	Prosopis.
Nitrogen only.	None.	4 to 6
2.67	0 to 1	1 to 5
4.5	0 to 2	2 to 5
7	1	2 to 5
10	4 to 5	9 to 11

It is thus seen that the roots of *Prosopis* continue growth for a longer time in a soil-atmosphere poor in oxygen, with no carbon dioxide, than is the case in *Opuntia*.

The oxygen, as well as the carbon-dioxide response, is thus known to be a specific one, at least as far as *Opuntia* and *Prosopis* are concerned, and thus it is a matter of ecological importance. The relative indifference of the roots of *Prosopis* to soil aeration permits them to grow deeply as well as shallowly, and permits the species to range widely as regards soils, although typical development of the species appears to occur along the river-floor plain, where the superficial soils at any rate are of a fine texture and where deep penetration is possible. In a similar manner the relative dependence of the roots of *Opuntia versicolor* on good soil aeration makes it impossible for the roots of the species to attain to any considerable depth and especially precludes the species from inhabiting soils that possess a fine texture and which in seasons of most active growth are inadequately aerated.

Modification of Root Habits by Experimental Means, by W. A. Cannon.

Among the questions associated with a study of root and root responses, the fixedness of habits in roots is a matter that attracts the attention of the worker who concerns himself with experimental modifications. In roots there is an especially good opportunity to observe the immediate influence of the soil environment upon inherited tendencies, and certain features of such studies have been reported, from time to time, in the Year Books of the Carnegie Institution of Washington.

The roots of all species are not equally adjustable to their environment, and such adjustability is directly dependent on soil aeration and temperature. An adequate moisture-supply is a condition *sine qua non* for root-growth of whatever type, and it does not figure to the same degree or in the same way as the feature mentioned as a character-determining factor.

So far as the observations show, it appears that roots which are capable of deep penetration of the soil, or that customarily grow in soils of fine texture, are less responsive to relatively small changes in soil aeration and may be less dependent on temperature than is the case with roots that are essentially superficial and which occur in relatively well-drained soils only. However, roots of the former type are apparently not all non-responsive to such changes. For example, *Pistacia atlantica*, which is native in the dayas of southern Algeria, has been found capable of making a slow growth-rate in the garden of the Coastal Laboratory, although the temperature of the soil is relatively low. In the growth and development of the root-system, of the species in the garden it was observed that a pronounced taproot was at first formed and the formation of laterals was not at

all pronounced. For two or more years shoot-growth in the species was slight. In about three years from the seed the growth of the shoot assumed a greater prominence, and it was found that lateral roots had begun to develop in a pronounced fashion. With the passing of time the development of the laterals was more accentuated, until at the end of about six years they constituted the most important part of the root system. It is of interest to note the behavior of the roots of *Prosopis velutina*, which was growing under the same circumstances. In this a taproot was formed at first, but owing to the low temperature of the soil at a depth of 1.5 m. it was of limited growth. No laterals were formed the first or succeeding year. The growth of the shoot stopped with the cessation of growth of the root and the species failed to become established.

Cultural experiments with species whose roots remain close to the surface of the ground, and with characters apparently especially well fixed, reveal a surprising plasticity in root development. This has been observed in certain cacti, particularly in *Opuntia versicolor*. In garden experiments with *Opuntia* carried out at the Desert Laboratory, where fine and coarse soils were used, the usual type of root development was seen in the finer soil, but there was a marked tendency to generalization in the roots growing in soil that was coarse. In other experiments the roots of *Opuntia* were observed to assume the extreme taproot habit, which under natural conditions never occurs. In these experiments jointed terra-cotta and galvanized-iron pipes, 2.5 m. in height and 7.5 cm. in inside diameter, were used. These were filled with coarse soil and placed in an upright position with the lower end resting in a large can. The pipes were thus exposed to the temperature of the air throughout their entire length. Two specimens of *O. versicolor* were planted in two of the pipes and one of *O. discata* in the third. When, after having been left growing for over three years, the cultures were taken down, the following condition was found: The roots of all of the *O. versicolor* plants had attained to the bottom of the pipes and had spread somewhat on the bottom of the supporting can. The upright length of the roots was thus 2.5 m. There were some unimportant laterals. *O. discata* formed several relatively slender roots of about equal length, which were approximately 1.5 m. long. The soil in all pipes was moist when the cultures were examined. Thus the roots were well aerated and there was a high temperature of the soil for the entire root-length during a portion of each year. It seems highly probable, therefore, that if the soil in the habitats where these cacti grow were at a depth of 3 m. sufficiently warm, adequately aerated, and at the same time moist, deeply penetrating roots would be formed by them. And, finally, it can not be said that in the cacti the distinctive root characters result from inherited tendencies, as is the case in *Prosopis velutina*, for example, but, on the contrary, that they

are expressions of the response of the species to the distinctive aeration and temperature conditions of the soil environment.

The Origin and Physical Basis of Succulence in Plants, by D. T. MacDougal and H. A. Spoehr.

Two types of succulent or fleshy plants are recognized by the botanist—those which like the cacti grow in dry regions, and those of the seashore, sometimes known as halophytes. The chief anatomical characteristic of these forms consists in the fact that tracts of thin-walled cells have become enlarged either by the multiplication of the number of cells or by the exaggerated growth of the original number, and in these cell-masses relatively large quantities of water or cell-sap are held. The origin and evolutionary development of this type of vegetation has been the subject of much speculation. Nearly all succulent plants are characterized by marked acidity of the tissues, and as many of the species inhabit localities in which the soil is highly charged with salts, these physical factors have been made to account for the accumulation of water in plants through the play of osmotic forces. All explanations of this character have, however, been found inadequate.

The discovery by Professor H. M. Richards of the fact that the *Castilleja* and the *Erigeron*, native to the region about the Coastal Laboratory, each included some individuals which were thin-leafed and others which were thick-leafed, and that these leaf characteristics were correlated with the water-supply of the plants, has furnished us the material upon which an explanation of succulence might be based.

The measurements of hydration or imbibition by plant tissues, which are discussed in several parts of this report, make it appear that the protoplasm of plants consists largely of pentosans, of which the mucilages are an example, mixed with a smaller proportion of protein derivatives, and some salts. Naturally, since succulence implies an increased storage of water, attention was turned to this water-holding mechanism of the cell in search of an explanation of its increased capacity.

The fundamental fact has been established, in series of analyses of the carbohydrates of desert plants, that when cells containing polysaccharides undergo a depletion of the water-content, these sugars are reduced to the pentosans, of which the mucilages are largely composed. The imbibition capacity of the polysaccharides is small. Their transformation from this form into that of the pentosans gives the increased capacity characteristic of the pentosans, so that without any addition of material to a cell, but simply by the loss of water, a change takes place by which the cell is capable of absorbing and holding vastly greater proportions of water. In other words, aridity by causing undue loss of water induces a change in the cell by which

the amount of water which they *may* hold is greatly increased. This results in giving the cell-mass a storage capacity which is permanent, as the pentosans are not reconvertible into the polysaccharides.

It is notable that in *Castilleja*, in which a detailed study of the above facts was made, the acidity of the thin-leaved plants is about double that of the succulents, which gives rise to the suggestion that it is in plants with high acidity, or rather with a type of metabolism which produces high acidity, that the development of succulence is possible.

That the change from the thin-leaved condition to that of succulence is not a simple one and that the biocolloidal complex presents a different aspect is evidenced by the following hydration reactions of both types of leaves in a fresh condition, after being swelled and dried, and freshly dried. The figures relate to July 28–31, temperature 16° C.

Hydration reactions of succulent and thin leaves of Castilleja.

	Succulent.				Thin leaves.			
	Water dist.	Citric acid, 0.01 N.	Potass. hydrate, 0.01 M.	Potass. nitrate, 0.01 M.	Water dist.	Citric acid, 0.01 N.	Potass. hydrate, 0.01 M.	Potass. nitrate, 0.01 M.
Fresh	<i>p. ct.</i> 143	<i>p. ct.</i> 95	<i>p. ct.</i> 125	<i>p. ct.</i> 90	<i>p. ct.</i> 140	<i>p. ct.</i> 120	<i>p. ct.</i> 60	<i>p. ct.</i> 76
Swelled and dried.....	20	16	20	60	132	12	67	153
Fresh-dried...	76	60	55	65	100	20	118	130

Osmotic Concentration of Tissue Fluids in relation to Geographical Distribution,
by J. Arthur Harris.

This work has been continued along the lines laid down in previous reports (Carnegie Inst. Wash. Year Book, 1915, p. 81; 1916, p. 79, and 1917, pp. 88–89).

A period of nearly a month was devoted to field work, with the assistance of Mr. Charles W. Crane, in the pineland, hummocks, and cypress swamps of the Lake Okeechobee region of southern Florida. Three periods of work, aggregating several weeks in duration, were devoted to the vegetation of the Dismal Swamp, with the cooperation of Dr. John Y. Pennypacker. Several hundred cryoscopic determinations were obtained in these highly interesting regions. Discussions of two phases of the work have been published during the year.

In a memoir on the vegetation of the Jamaican Coastal Deserts, published with Mr. John V. Lawrence (Bot. Gaz., vol. LXIV, pp. 285–305), the conclusions concerning the high osmotic concentration of the tissue fluids of desert plants based on earlier studies on the Arizona deserts (Phys. Res., vol. II, pp. 1–50, 1916) have been fully con-

firmed. One of the most interesting results of this investigation is that the cacti, although growing in close association with typical halophytes, have the low osmotic concentration of those growing in non-saline deserts.

An investigation of the osmotic concentration of the fluids of desert Loranthaceæ (Mem. Torr. Bot. Club, vol. xvii, p. 307-315,) has demonstrated that the leafless *Phoradendron californicum* and the leafy *P. coryæ* and *P. macrophyllum* of the Arizona deserts show an osmotic concentration which is, roughly speaking, twice as great as that demonstrated by the same methods in the tissue-fluids of the species investigated in the montane rain-forest of Jamaica (Harris and Lawrence, Amer. Jour. Bot., vol. iii, p. 438-453, 1916). In desert Loranthaceæ, as in those of the montane rain-forest, the osmotic concentration of the tissue-fluids is generally, but not invariably, higher than that of the host.

A paper on the osmotic concentration of the fluids of epiphytic plants, based on investigation in Jamaica and Florida, is now in press. In this it is shown that the osmotic concentration of the tissue-fluids of epiphytic Bromeliaceæ, Orchidaceæ, Piperaceæ, and Gesneraceæ is far lower than that of terrestrial vegetation. In the Jamaican montane rain-forest, where data for direct comparisons for individual habitats are available, the epiphytes show from 37 to 60 per cent of the concentration characteristic of herbaceous terrestrial vegetation, and from 28 to 44 per cent of the concentration of ligneous terrestrial vegetation. In the Bromeliaceæ, Orchidaceæ, and *Peperomia* of the Piperaceæ the osmotic concentration of the species of the Jamaican montane rain-forest is lower than that of the species of the hummocks of subtropical Florida.

At some future time it is hoped to deal with the problem of the osmotic concentration of cryptogamic epiphytes and to obtain data on the inorganic and organic constituents of the fluids of epiphytes which will justify further discussion of the physiology of these ecologically remarkable forms.

PLANT BREEDING.

Culture of a Potato Hybrid, Solanum fendleri × *S. tuberosum* ("Salinas"),
by D. T. MacDougal.

Cultures of the hybrid between the wild potato of Arizona and the domestic variety cultivated in the vicinity of the Coastal Laboratory have been carried on at the Desert Laboratory, at the Coastal Laboratory, and on a ranch in the valley of the Carmel River. The cooperative experiments of Professor George H. Shull, of Princeton University, in which an analysis is being made of the domestic parent, have resulted in a separation of a large number of elements of different value.

The reproduction of this plant by its tubers makes it possible to preserve each generation for comparison, as a result of which some of the first, second, and third generations are now represented. Flower and foliage characters of the smaller wild parent continue to determine the general aspect of the shoots and flowers even in the third generation. Only tubers of small size have yet appeared in the cultures. It is to be noted that the tubers produced by plants grown from seed may not reach the maximum and that two or three seasons of propagation by tubers may be necessary to accomplish this. About a dozen strains of possible economic importance are receiving special trial in a plot of virgin soil. The hybrid in general shows increasing vegetative vigor with each successive generation produced by seed. The technical analyses of the reactions of the qualities of the parental species will be reserved for detailed description.

DEPARTMENT OF EMBRYOLOGY.

GEORGE L. STREETER, ACTING DIRECTOR.

At the outset of the current year the Department of Embryology suffered an irreparable loss through the death of its Director, Professor Franklin P. Mall, on November 17, 1917. Owing to his wide influence in the development of scientific medicine and medical education, this great blow is not limited to our department alone, but also deeply concerns the medical profession at large, and particularly all those who are interested in the advancement of the science of human embryology.

At the time of his death Dr. Mall was engaged in the preparation of two papers; one, a monograph on the implantation of the human ovum, which was being prepared in cooperation with Dr. J. Whitridge Williams, who has undertaken the completion of the study; the other, an analytical survey of all the pathological ova in the Carnegie Embryological Collection. This was to be a joint paper with Professor Arthur W. Meyer. The plan of the study had been definitely laid out and the work had advanced far enough to enable Professor Meyer to continue it without interruption. It is now nearly completed.

Since the last report two studies by Dr. Mall have been published. One of these concerns the frequency of localized anomalies in human embryos and infants at birth. An embryo normal in form, even though it be surrounded by diseased or deformed membranes, is classed by him as *normal*, on the theory that the pathological conditions under which it may have developed were not sufficiently serious to produce any change in the embryo. If the latter is normal in all but one respect it is termed *normal with a localized anomaly*. As far as can be determined, such an embryo would have survived but for the factor that caused the expulsion of its membranes. It is from this group that one might expect monsters at term.

The pathological embryos show a variety of changes ranging from macerated fetus and fetus compressus to complete disintegration of the ovum, where only a few villi are left. These are segregated by Dr. Mall into seven groups according to the severity of the process. Tables covering the first 1,000 specimens in the collection show that 396 (nearly 40 per cent) are pathological, of which 31 per cent are uterine and 9 per cent ectopic. Localized anomalies were present in 10 per cent of the pathological embryos, while in the normal group they occurred in 6 per cent of the cases. All of the pathological specimens, whether with or without localized anomalies, were aborted during the first half of pregnancy. Specimens belonging in the normal group usually fall within the first five months, but older ones are occasionally met with, there being one in the sixth, one in the eighth, and five in

the tenth month. In a previous monograph on the causes underlying the origin of human monsters, Dr. Mall calculates that there are 80 full-term births to every 20 abortions, and that the birth of monsters is noted at about the rate of 30 to every 5,000 pregnancies. Among the 1,000 cases under consideration there were 5 monsters. It follows, therefore, that 25 should occur in 4,000 additional full-term births. This, together with the incidence of localized anomalies (7.5 per cent) makes it apparent that anomalies in aborted embryos occur with about 12 times the frequency of full-term monsters. The conclusion seems to be justified that pathological embryos, as well as those normal in form, are frequently associated with localized anomalies, and that the terminating abortion usually is the result of lesions of the chorion and its environment. Should these be slight and the uterine inflammation be overcome, pregnancy in all probability would go on to term, ending in the birth of a monster or malformed infant. Furthermore, it is probable that monsters are not germinal or hereditary, but are the result of external influences acting upon the ova.

The other paper referred to is a study on the age of human embryos, which was in press at the time of Dr. Mall's death and has since appeared. This supplements his chapter on the same subject in the *Manual of Human Embryology* (Keibel and Mall, 1910). In the latter he gives a curve of growth, constructed upon measurements, menstrual age, and date of abortion, for 1,000 specimens from the various months of pregnancy, and from this he computes the mean menstrual age. To the curve he adds the copulation age wherever known, and this was found to fall into position 10 days after the mean menstrual age.

As pointed out by Bryce and Teacher, and now generally accepted, it is probable that the menstrual cycle in man is homologous with the œstrus cycle in lower mammals. Menstruation corresponds to the proœstrum, and apparently a vestige of œstrus still persists, since conception is of more frequent occurrence at that time. This view is confirmed by the records of the Carnegie Laboratory. Dr. Mall tabulates a series of 25 such cases in which the menstrual and copulation ages are given, and adds several others from the literature. Only 6 of these, however, each representing the product of a single copulation, are regarded as absolutely reliable. In these the records fall almost exactly upon the above-mentioned curve.

The time of ovulation is still open to question, as very young human ova accompanied by ovaries are extremely difficult to obtain. In the Carnegie Collection there is but one such specimen, the ovum measuring 5 by 3 mm. In this the corpus luteum is well-formed, solid, and contains no blood. In Herzog's specimen, 2.3 by 1.2 mm., the corpus luteum is described as "fresh but closed." Fraenkel asserts that ovulation takes place about the nineteenth day after the cessation

of the menstrual period, but the work of Meyer and Ruge completely overthrows this theory. According to the latter, ovulation occurs some time during the first 14 days of the menstrual month, a theory which coincides with that of Dr. Mall.

Regarding fertilization, resort is had to both comparative and clinical studies, and the conclusion is drawn that the fertilizing power of the sperm is of relatively short duration, shorter, probably, than the fertility of the ovum, and that therefore fertilization occurs within 24 to 48 hours after ovulation. It seems likely that fertilization takes place nearly always within the tubes, ovarian pregnancy being extremely rare. The best clinical data point to a week of sterility before the onset of menstruation, and a fertile period of 15 days following its cessation. The average time of conception is probably about the tenth day, accepting one day as the time elapsing between ovulation and fertilization.

The Contributions to Embryology, a series of embryological papers started by Dr. Mall and heretofore published under his editorship, have been continued, and during the past year the following two volumes have appeared:

Publication No. 227 (Contributions to Embryology, Vol. VII):

- No. 20. The histogenesis and growth of the otic capsule and its contained periotic tissue-spaces in the human embryo. By George L. Streeter.
- 21. The genesis and structure of the membrana tectoria and the crista spiralis of the cochlea. By O. Van der Stricht.
- 22. Study of a human spina bifida monster with encephaloceles and other abnormalities. By Theodora Wheeler.
- 23. A human embryo before the appearance of the myotomes. By N. William Ingalls.

Publication No. 271 (Contributions to Embryology, Vol. VIII):

- No. 24. The developmental alterations in the vascular system of the brain of the human embryo. By George L. Streeter.
- 25. The mitochondrial constituents of protoplasm. By E. V. Cowdry.
- 26. The development and reduction of the tail and of the caudal end of the spinal cord. By Kanae Kunitomo.

In connection with his studies on pathological embryos, undertaken conjointly with Dr. Mall, important observations have been made by Professor Arthur W. Meyer concerning the process of hydatiform degeneration. Two papers on this subject are now in press. Dr. Meyer finds that, instead of being a rare condition, this is one of the most common forms of degeneration of the chorion and constitutes an important factor in the cause of abortion. Microscopical examination of 348 uterine and 106 ectopic specimens, classed in the Carnegie Collection as pathological, yields the following results: Of the uterine cases which were in a sufficiently good state of preservation to admit of diagnosis, there are 113 (32.4 per cent) that show hydatiform degeneration. In the 106 ectopic specimens 44 (41.9 per cent) present the same condition. The incidence of hydatiform degeneration in specimens containing normal embryos is not determined. It was

observed incidentally in some cases, and making allowance for this, Dr. Meyer calculates that the actual incidence in 2,089 specimens, both normal and pathological, would be 10.9 per cent in the uterine and 20.8 per cent in the ectopic cases. The increase of 100 per cent in the incidence of the condition in the tubes may be due to the less favorable nidus found there. If so, it throws a significant light upon the probable cause of hydatiform degeneration, which would seem to lie in the conditions surrounding implantation rather than in the ova or spermatozoa themselves.

The prevailing belief that the disease is more commonly met with at or near the menopause is not confirmed by the records of the Carnegie Collection. In the uterine cases the average age of 36 women was 31 years, which was about equaled in the ectopic cases, where in 20 women it was 33.9 years. In the uterine group 19 out of 41 women had aborted for the first time, 12 had aborted twice, and 10 more than twice; 9 out of 33 women had borne once, 18 twice. Of the ectopic group 8 out of 23 women had borne but once, 4 twice, and 3 more than twice, and 14 had aborted once. That a number of these women had borne 1 or 2 normal children would signify that the endometrium was normal at the time of marriage. As to the time of expulsion of hydatiform moles, it is found that the average menstrual age in 51 uterine cases in which it was given was 66.6 days. In 25 ectopic cases it was 43.4 days, most of these specimens being young, empty chorionic vesicles, or remnants of such.

Certain criteria regarding the diagnosis of early hydatiform degeneration are emphasized by Dr. Meyer. He urges the most careful examination of the chorion with the binocular microscope, by the aid of which typical changes in the villi can often be detected. He also points out that the process begins in the stroma and is associated with the centripetal degeneration and disappearance of the blood-vessels. The epithelium, in contrast to the stroma, is usually in a splendid state of preservation. It may or may not show active proliferation. Dr. Meyer is to continue these studies, and the attention of physicians is called to the important bearing which this disease may have in cases of repeated abortion of unknown cause. When the diagnosis is uncertain, specimens should be submitted for examination.

An entirely different type of pathological process has been studied by Dr. Theodora Wheeler, and attention may be called to her paper on a human spina bifida monster. Until quite recently investigations of this condition have been based upon external form alone. Dr. Wheeler selects a typical example of the group known as iniencephaly and applies to it the more exact anatomical methods, with the result that an unexpected series of anomalies is encountered. It is from such data alone that we can hope to bring these fetal abnormalities into harmony with known embryological facts and thus arrive at their etiological classification.

Hitherto our information regarding sex ratio in man (the proportion of males to every 100 females) has been derived from statistics of the new-born and adult, while the sex ratio in uterine life has been represented only by a few conflicting estimates. The paper of Dr. A. H. Schultz on this problem is, therefore, of especial interest. His study is based upon 600 fetuses from the Carnegie Collection and 57 additional ones published by Rauber.

Dr. Schultz distinguishes between the sex ratio at the time of conception, which he terms *original* or *primary* sex ratio, and that at birth and in the adult, which he terms respectively as *secondary* and *tertiary*. After outlining the changes in sex ratio during the secondary and tertiary periods, due to the unequal mortality of the two sexes, he discusses the factors involved in the primary sex ratio, and particularly the relative frequency of abortions and stillbirths of the two sexes. In general he finds that the sex ratio of intrauterine mortality is higher than that of the living fetuses. As it is not possible to determine the sex by external examination in the first two months of pregnancy, there are no data for this period. In the third month the mortality of males is about 25 per cent higher than that of females. From the fourth to the seventh month it is nearly equal in the two sexes. During the eighth to the tenth month the relation again shows a higher mortality for the males. The author concludes that more males, to the extent of not more than 10 per cent, are conceived, and that at certain periods of pregnancy the relative mortality of males exceeds that of females by as much as one-fourth.

In a critical discussion of the changes in the sex ratio of new-borns it is pointed out that most of the factors claimed to affect the ratio, such as pelvic diameters of the mother, Jewish race, social class, illegitimacy, war, etc., are not sex-determining but sex-eliminating; *i. e.*, they increase or decrease the relative frequency of abortions and stillbirths with their high sex ratio, thus altering the primary sex ratio during the period of pregnancy.

The matter thus far referred to in this report deals with problems of human embryology in its more general aspects. Other studies that have been published during the past year will now be referred to under two separate headings—cytology, and studies concerning individual systems.

CYTOLOGY

The activities of this department in the field of cytology have continued along lines similar to those of last year. They include a group of studies based upon tissue cultures and another group based upon fixed material and dealing particularly with the subject of chondriosomes (mitochondria).

By means of tissue cultures M. R. Lewis and W. H. Lewis have been able to make important observations on the growth and behavior

of muscle-fibers. In one of their papers on this subject they describe the striking histological character of muscle outgrowths in tissue cultures. This is the first time that the growth of cross-striated muscle-fibers under such conditions has been described. The authors succeeded in obtaining abundant outgrowths from the skeletal muscles of chick embryos, using Locke-Lewis solution with or without the addition of other substances. Small bits of muscle were taken from the trunk or extremities of chick embryos 4 to 6 days old, in which the muscles are not yet cross-striated, or from 7 to 9 day embryos where the muscle-fibers showed striation. Muscle-buds, growing out from the cut ends of the fibers, begin to project from the edges of the explanted pieces at the end of the first day after being placed in the culture medium, and reach their maximum growth at the end of the third or fourth day. It is of interest to note that, whereas the fibers of the explanted piece retain their characteristic differentiation, the sprouting buds show at the beginning a younger embryonic appearance and are devoid of cross-striations. The growing protoplasmic ends of the muscle-buds creep out by active amœboid motions along the cover-slip, pulling out the more proximal part of the bud and often exerting considerable tension, resulting sometimes in the rupture of the connecting strand. There is a marked tendency toward anastomosis and fusion of neighboring fibers or of their branches. The buds show many nuclei and the cytoplasm has a fine, longitudinal striation, but there is no indication of real sarcofibrils. Chondriosomes are abundant, and there are a few small, red granules. In addition to the muscle-buds the authors usually found many free, wandering fibers or myoblasts, containing from one to many nuclei. The whole picture of muscle-buds in tissue culture presents a marked similarity to that of the initial stages of regeneration of muscle in mammals, and apparently the process in the two is essentially the same.

In another paper the same authors have published the results of a study of the contraction phenomenon of smooth-muscle cells in hanging-drop preparations of the amnion of the chick. The amnion of young chick embryos is composed of a single layer of epithelial cells overlaid by a thin layer of mesenchyme cells which differentiate into smooth-muscle cells and undergo definite contraction as early as the fourth or fifth day of incubation. In tissue cultures smooth-muscle cells grow out from the explanted piece of amnion unmixed with epithelial cells, so that their behavior and structure can be accurately observed. The authors found that the power of rhythmical contraction exists in smooth-muscle cells under these conditions and that it is an inherent property of the protoplasm of the cell. It may be exhibited either by a bundle of cells, by an individual cell, or by a part of a cell. When the phenomenon has ceased it can be instituted again, either by touching the cell or by washing the preparation with

a drop of culture medium to which an increased amount of calcium has been added. From a microscopic study of the contracting cells it became apparent that the cytoplasm, which is quite elastic, plays the most active part in the contraction; while, so far as could be seen, the nucleus, the nucleolus, and the chondriosomes take only a passive part. There are no myofibrils present in these living, contracting smooth-muscle cells. In the act of contracting the cytoplasm is accumulated at a given point at the expense of the surrounding region, forming a thickened and folded mass called the *contraction node*. Coincident with the contraction of a muscle-strand there usually occurs a swaying or pendular movement of its substance, so that it is thrown in a curve, this movement being more pronounced during relaxation than during contraction.

The effect of a group of vital stains upon the eggs of *Cerebratulus lacteus*, *Echinarchinius parma*, and *Lophius piscatorius* has been studied by Margaret Reed Lewis, with the object of determining the effect of such stains upon the fertilization of eggs and the later development of the embryos, and especially as to whether they are in reality vital stains which will stain the granule of a cell without injury to either the cell or the developing embryo. Mrs. Lewis found that the spermatozoon and the unfertilized egg are both sensitive to the toxic effect of all stains, especially janus green. After the eggs are fertilized they become progressively more resistant, although a sufficiently strong solution of any of the stains would cause the death of even the older embryos. If used in weaker solutions brilliant cresyl-blue 2b and neutral red proved to be true vital stains, the granules of the cells being deeply colored without interrupting the development of the embryo. On the other hand, it was found that janus green, under such circumstances, is not a vital stain, for not only did it usually prevent fertilization of the egg, but also in every case where the solution of the stain was of sufficient strength to color any of the granules of a cell it killed the embryo. It is interesting to note that individual stains show an affinity for certain types of granule. Two definite types are stained—one by janus green, the other by neutral red, those stained by the former probably being the chondriosomes. Similar results are obtained by the application of the same dyes upon spermatozoa in which the middle piece or chondriosomal body is stained by the janus green, while a granule on one side of the head of the spermatozoon is colored with neutral red. In addition to these two types of granules, there are the yolk or fat globules, which do not stain in the living embryo, either with neutral red or janus green.

Investigations regarding the character and distribution of chondriosomes have been carried on by E. V. Cowdry, N. H. Cowdry, and J. Duesberg. The comprehensive paper on this subject by Professor E. V. Cowdry will be reviewed in our next report. The relation-

ship of plant and animal mitochondria (chondriosomes), concerning which there has been considerable difference of opinion in the literature, has been studied by Mr. N. H. Cowdry. The author has approached the problem from both its chemical and morphological aspects, including new methods of technique in the form of supravital dyes of the janus-green series, which had not previously been applied to plant cells. He finds that, just as mitochondria are universally present in animals, so do they occur in all plants, with the exception of some of the lowest forms (myxomycetes and certain algæ), and even in these groups structures are present which may ultimately prove to be mitochondrial. In their morphology the mitochondria are identical in plants and animals, showing in the two species similar variations in size and shape in the different tissues and different cells. Similar fixatives preserve them, modify them, and destroy them in like manner in plants and animals. Plant mitochondria react to the janus-green test and stain with supravital dyes in substantially the same way as animal mitochondria. It is, however, more difficult to obtain a good coloration. Their composition, as indicated by solubility with respect to acetic acid, heat, and other reagents, is subject to similar variations in both. All points of comparison of mitochondria in plant and animal cells thus bring to light a striking degree of similarity. One must conclude that this general similarity and wide occurrence are an indication that mitochondria are an essential constituent of living matter.

In studying the chondriosomes in the testicle cells of *Fundulus*, Professor J. Duesberg has followed a subject of especial interest because of the possible rôle these structures may play in heredity. He finds that in the cells lining the distal part of the excretory ducts the chondriosomes are represented by long chondriococts whose arrangement reminds one of Heidenhain's or Pflüger's rods. In the proximal part of the excretory ducts the chondriosomes are replaced by granules of pigment. The connective tissue of the testicle contains a number of cells with special protoplasmic structures—bacillus-shaped chondriococts and secretion granules, and these are probably to be regarded as interstitial cells. Chondriosomes are found in all generations of germ-cells and are transmitted during mitosis from one generation to the next. Coarse and irregular in shape in the spermatogonia, they become equal in size and spherical in the spermatocytes. Their number is obviously reduced during the period of maturation; in the young spermatid it can be estimated at eight or thereabouts, and finally, in the ripe spermatozoon, it is reduced to three, evidently as the result of fusion of the granules and condensation of their substance. The chondriosomes are located at the posterior part of the head and consequently close to the origin of the tail. The various stages of the spermatogenesis of this form are illustrated in Professor Duesberg's paper.

STUDIES CONCERNING INDIVIDUAL SYSTEMS

Under this heading I will refer first to a group of papers which concern problems of the bony and muscular systems, and later will take up other papers falling into three groups: Vascular system, genito-urinary system, and central nervous system.

In order to ascertain the differences existing between whites and negroes in the relation of the external nose to the bony nose and nasal cartilages, Dr. Adolf H. Schultz studied the subject in a number of skulls of both races, ranging from the eighth month of intrauterine life to the adult stage, and including male and female. The height of the external nose corresponds to the nasion-subspinal point measurement, but the subnasal and subspinal points do not lie in the same level. In fetuses the subspinal point lies below, in adults above the subnasal point. The difference between the two measurements in favor of the external nose is greater in negroes. The external nasal breadth and the breadth of the apertura piriformis are so variable that no correlation could be obtained. The nasal septum and the lateral and greater alar cartilages, on the other hand, show well-marked racial differences. In whites the cartilago septi nasi forms a quadrangle, in most cases a trapezium; in the negro it is triangular. The size of the lateral nasal cartilage varies greatly in both whites and negroes, but in general, in spite of these irregularities, it may be said to be slightly smaller in the latter. In the whites a lower posterior border can be distinguished, but in negroes this is entirely lacking, the lower border running in either a horizontal or posterior-superior direction. The greater alar cartilage may also present great variations in form and size, but on the whole is more developed in the white race. In the intervening space minor alar cartilages are found in varying sizes and numbers. In the whites these were present in 75 per cent, in the negroes in only 30.4 per cent of the cases. The fact that all the nasal cartilages are more developed in the white race is probably attributable to the greater prominence of the nose, and hence a demand for more cartilaginous support. The nose is morphologically a progressive structure, the increase in prominence during growth being due to the reduction of the dental arch. This important study is now being extended by Dr. Schultz to the earlier fetal stages.

As somewhat related to the preceding topic, Dr. Schultz has studied the occurrence of and factors involved in the formation of the metopic fontanelle, which is an anomaly rather frequently found in the newborn infant. In his paper he describes the presence of an abnormal suture in the skull of a negro 55 years of age, which he interprets as a remnant of that fontanelle.

In connection with the muscular system Dr. Schultz has undertaken a metrical study of the insertion of the pectoralis major and deltoid muscles. The metrical determination of the position of the muscle

attachment is an important point in topographical anatomy and musculo-mechanics, and is of no less interest to the anthropologist. Dr. Schultz studied the insertion of the two muscles in both the right and left humerus in white and negro cadavers. The measurements were taken projectively and expressed in percentages of the absolute lengths of the humeri. From these were obtained indices of position, standard deviation, and variation coefficients, which show the possibilities of variation in the insertion of the two muscles. The deltoid possesses a more constant position of insertion than the pectoralis major muscle. No racial difference was observed, but the insertions showed a marked difference in the sexes, the pectoralis major being more proximally attached in the female. Asymmetries are surprisingly common, and individuals with an exactly equal position of muscle insertion on the two sides may be considered as exceptions.

In this connection it may be mentioned that the Zurich inaugural dissertation of Dr. Schultz on anthropological studies on the base of the skull has come from press during the past year.

In the last report the work of Dr. John C. Koch on the laws of bone architecture was referred to, and since then this has been extended to a study of the distribution of fractures of the femur in a series of cases treated at the Johns Hopkins Hospital. It was found that the actual distribution is in close agreement with the theoretical, as calculated from a mathematical analysis of the architecture of the normal human femur, and that the tendency to fracture at any point varies inversely as the least strength in that segment.

Dr. C. C. Macklin has completed his study on experimental calcification of tissues in madder-fed animals, an account of which was given in the last report, and his paper has now appeared in its final form. As a somewhat related subject Dr. Macklin has studied also the formation of callus in the process of bone repair in rats vitally stained with trypan blue. He finds that following the first inflammatory reaction macrophages congregate in great numbers at the site of the injury, being most active from the third to the sixth day, at which time they begin to undergo disintegration. During the removal of the callus, from the tenth to the twentieth day, other cells derived from its spaces, and resembling macrophages of developing bone, show a marked reaction to the vital dye, thus manifesting their phagocytic activity. A preliminary account of this work has appeared and the completed paper is now in press.

The preceding report from this department contained an account of two papers published by me regarding the histogenesis of the connective tissue and cartilaginous coverings of the membranous labyrinth. This study has been extended and has since appeared in completed form as one of the papers in Publication No. 227 of the Carnegie Institution of Washington.

The study of the development of the vascular system of the head in the human embryo was initiated in this laboratory by Professor Mall in 1905. Later I undertook the same investigation and reported some of the features of the adaptive metamorphosis of the dural veins, as referred to in our report for the year 1915. Since then it has been carried farther and the results have been published in completed form. In this paper it is pointed out that a primordial or precirculatory period exists, during which the vessels of the head are engaged in differentiation and growth in the elaboration of a plexus. Their form at this time is not influenced by conditions that would favor the efficient circulation of the contained blood, and they are not to be considered as arteries or veins, but rather as a germinal bed from which arteries, veins, and capillaries are subsequently derived. Later, as the circulatory flow of the blood becomes established, the blood-channels respond by conforming to the hydrodynamic requirements and the plexus is resolved into a capillary bed with favorably situated aortic feeders and simple and direct venous drainage channels. This constitutes the primary type of the circulation in the head. The paper then describes an interesting series of adjustments in the arrangement of the blood-vessels in adaptation to the developmental alterations in the form, size, and condition of the structures of the head region, the process being followed by the attainment of the adult arrangement. It is pointed out that the vascular apparatus is continuously adequate and complete for the structures as they exist at any particular stage; as the environmental structures progressively change, the vascular system also changes and thereby is always adapted to the newer conditions.

A distinct advance in our knowledge of the differentiation of vascular endothelium has recently been made by Professor F. R. Sabin through the study of living preparations of the growing chick. By this means it was possible to observe directly the principal steps in blood formation. Certain phases of the process that were still under dispute, as well as others which were new observations, have thus become established. According to Dr. Sabin's description, the vaso-formative cells or angioblasts are differentiated from the mesoderm, and on proliferation they form small, dense, syncytial masses which join one another by means of tiny processes of cytoplasm. In this way are formed plexuses of solid angioblastic cords, the growth of which is maintained partly by proliferation of their constituent cells and partly by the further addition of new angioblasts, which differentiate from the adjacent mesoderm. During the formation of these angioblastic plexuses there occurs a liquefaction of their cytoplasm in such a manner as to convert the solid angioblastic cords into vessels filled with a clear fluid. This is brought about by a process of vacuolization and the formation of an intracellular lumen. Vacuoles appear near

the nuclei and rapidly enlarge, so that in from one to two hours there is complete destruction of the cytoplasm and nuclei of the central part of the angioblastic cords, resulting in the formation of a clear plasma, the periphery of the mass being preserved as an endothelial boundary.

The liquefaction of the cytoplasm occurs both in the loops of the angioblastic plexuses and in masses of angioblasts that are still isolated, in the latter case resulting in small vesicles that subsequently join the main plexus. These observations were made for the most part in the area pellucida of the yolk sac, but the same phenomena were also seen within the body of the embryo. The dorsal aorta in the trunk region and a portion of it within the head were seen to differentiate *in situ* in the above manner. The angioblasts are not all converted into endothelium and blood-plasma; a portion of them take part in the formation of red blood-corpuscles. During the lumen formation in the angioblastic strands small clumps of the original angioblasts become partially separated by liquefaction of the cytoplasm around them. Such masses soon show the presence of hemoglobin and constitute blood-islands that eventually float away in the blood-plasma and break apart as free, red blood-cells. Blood-islands can also be seen to be derived secondarily from the endothelium. This work has been continued by Professor Sabin during the past year, and a further account will be embodied in our next report.

The development of the lymphatic vessels of the heart has been studied in embryo pigs by means of injection methods, by Mr. James R. Cash. He finds that the lymphatics arise from two sources—the right lymphatic duct and the tracheal plexus, both of which send vessels to the lungs and act as pathways of drainage in the adult heart. A pericardial plexus is formed, which covers the entire heart and reaches its greatest density when the embryo is about 60 mm. long, decreasing with subsequent growth. From the injections it appears that when this plexus is approximately complete its vessels invade the heart-muscle and by anastomosis form the myocardial plexus. This becomes less dense as the deeper points of the myocardium are reached. At the 60 mm. stage no lymphatic vessels could be seen to extend into the myocardium, although short lymphatic buds were observed along the larger vessels of the pericardial plexus. Injections at this period failed to fill any of the pericardial lymphatics, and it is therefore probable that this plexus is almost completely formed before the invasion of the myocardium. Like all other lymphatics, those of the heart develop along the path of the blood-vessels. The author finds, however, that the pattern of the lymphatics does not correspond to that of the blood-vessels, and also that the lymphatics are not so numerous as has been supposed.

Extending his studies to the lymphatics of the stomach, Mr. Cash found, by injecting the retroperitoneal sac in embryo pigs, that numerous lymphatic sprouts pass into the stomach at the esophageal opening around which they develop, growing out in all directions. Two large vessels sweep ventralward under the spleen to the greater curvature and toward both cardia and pylorus, anastomosing with other branches from the ring. In embryos 60 to 70 mm. long the stomach is well covered with lymphatics and several vessels are sent from the retroperitoneal sac directly to the pylorus, through the duodenal mesentery. In older specimens the plexus in the pyloric region is much more dense and its vessels smaller than in other parts of the stomach. Two large lymphatic vessels can be seen microscopically, one in the loose, subserous tissue, the other in the submucosa. These are very dense and are connected by a less dense plexus which traverses the muscularis. Numerous branches from the submucosal plexus run in close relation to the blood-vessels.

A detailed morphological study of the development of the seminal vesicles in the human embryo has been made by Dr. Ernest M. Watson. He traces their structure and topography from the time they first appear as lateral evaginations from the Wolffian ducts in fetuses 80 mm. long up to birth. Dr. Watson has also completed an accurate study of the verumontanum in the human embryo, tracing its development and noting particularly the morphogenesis of its glandular elements. He finds that definite glandular tubules, arising from the evagination of the urethral mucosa, appear at the fourteenth week (fetuses about 100 mm. CR length). A second group of tubules of prostatic origin appear in fetuses 130 mm. CR length. Finally, in fetuses 221 mm. CR length a third group of tubules is observed in the mucosa of the prostatic utricle. All three groups can be clearly identified in the 270 mm. fetus.

While studying the fissura hippocampi in human embryos, Dr. Marion Hines has discovered that, although the transitory fissures, which are usually seen on the median wall of the cerebral hemisphere in the brains of embryos of 14 to 20 weeks' development, are artefacts, in embryos from 7 to 14 weeks the wall is not perfectly smooth. It shows at this time a shallow but complete infolding from the rostral to the caudal pole. The nervous tissue which lies at the bottom of this groove consists of an inner, narrow, nucleated zone, and a wide area devoid of cells. In the early stages this is the only part of the cerebral hemisphere in which the matrix and marginal velum of His are distinct. In an 11-mm. embryo it occupies the medio-dorsal sector of the cerebral invagination; at 14 mm. it lies more medial, and at 20 mm. it is almost centromedial. This sulcus, deepened by maceration, is doubtless the fissura hippocampi of amphibians and reptiles. Ventral to the fissura, in the rostral medial sector, is an

area resembling the septal nucleus of lower vertebrates. Dorsally it is continuous with the fascia dentata and is separated from the latter and from the fissura by a ventricular sulcus. The anterior commissure appears in embryos about 39 mm. long, the dorsal commissure in embryos about 60 mm. long. The course of development of the medial olfactory cortex is as extensive in man, therefore, as in other vertebrates.

Professor Kanae Kunitomo, who spent some time with us last year, studying certain features in the development of the tail and of the caudal end of the spinal cord in human embryos, has published the results of his investigations. His study is based upon profile reconstructions of the caudal region in 44 human embryos, ranging in length from 4 to 125 mm. and representing the entire period of development of the caudal appendage and also the subsequent period of its gradual reduction. He shows that in very young specimens the spinal cord reaches the extreme tip of the tail, and throughout its length is quite uniform in structure. Somewhat later (embryos 11 to 15 mm. long) it can be divided at about the level of the thirty-second vertebra into two parts; a cranial or main part, in an advanced stage of development, and a caudal, slender part, retarded in development. The main part, lying cranial to the thirty-second vertebra, undergoes uninterrupted and progressive differentiation, whereas the portion caudal to this undergoes regressive changes and, with the exception of its extreme tip, finally becomes converted into a fibrous strand, the tip forming the coccygeal medullary vestige. This, therefore, is an instance in which a tissue undergoes reversion to an earlier embryonic type, followed by a certain amount of subsequent redifferentiation. Another instance of the same process was referred to in the last report in connection with the growth of the cartilaginous capsule of the ear.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. DAVENPORT, DIRECTOR.

The exigencies of the world war have called for the assistance of every able-bodied man who could be spared from his family and whose ordinary occupation was such that it could be temporarily replaced by work of more immediate aid in the crisis. The response of those in this Institution has been facilitated by the generous action of the Trustees. Consequently, of the staff of this Department, three besides the Director, or over half in all, have at this writing temporarily left their work at the Station to assist in the war. Dr. E. Carleton MacDowell, a member of the Society of Friends, was the first to answer the call. He began to train in June 1917, and later in the summer he sailed for France as one of a reconstruction unit of the Red Cross. In France he helped rebuild homes in the devastated area; sometimes only a few miles back of the trenches. Meanwhile his experiments on the effect of alcohol on the germ-plasm of rats have been continued, along lines planned by him, with the aid of his effective assistant, Miss Emilie Vicari.

Dr. Charles W. Metz was unable, for physical reasons, to enter the service as a combatant. In the early autumn of 1917 he answered the call sent out first by the Red Cross for assistance with anti-malaria work in the neighborhood of the southern cantonments. He was shortly after transferred to the Public Health Service. He served at Hattiesburg, later at Montgomery, Alabama, and at Lakeland, Florida, making investigations into the problems of elimination of the malarial mosquito. Malaria, formerly so dangerous an enemy of soldiers in semitropical and tropical countries, was reduced in our southern camps last summer to negligible proportions by the work in which Mr. Metz is participating.

In October 1917 the Director of the Department became a member of the committee on anthropology, National Research Council. This led eventually to his appointment as major in the Sanitary Corps of the Medical Department of the Army. As head of the section of anthropology, division of medical records, he looks after the interests of the physical examination service of the Army, and assists the Army in questions of racial dimensions and differences; he has also participated in the statistical treatment of the data of the division of medical records.

On August 9, Dr. Oscar Riddle was appointed captain in the Sanitary Corps, U. S. Army, to assist, with his expert knowledge of biochemistry, in the work of the food division.

Of those members of the staff who have not, at this writing, entered the Army, two have been unable to do so because of their duties toward

*Situatd at Cold Spring Harbor, Long Island, New York.

their families of young children, and one because he has undertaken, as a war measure, an extensive project for perfecting a superior race of prolific beans. The spirit of response to the urgent call of threatened civilization has not been the less complete in those who have served at home.

Of those who a year ago were assisting the staff, all the young men except one are in the service. On account of loyalty to their work, and often against their best interests, they remained with us until definitely called to aid in the war. In the autumn Mr. B. T. Avery left with his regiment for France and died there. Mr. Donald S. Welch and Mr. Karl E. Anderson answered the call in the spring. Others of our assistants of last year are now in the service as combatants or in the Medical Corps. With one exception all laboratory assistants have been replaced by women.

ACCOUNT OF RESEARCHES IN PROGRESS.

On account of war conditions no attempt will be made in this report to analyze the relations of the work done to the general problem of evolution. Our first effort has been to maintain breeding-lines upon whose continuity the success of future work depends. This continuity is insured by the able assistants who are carrying on the strains while members of the staff are in various lines of war work.

Since early in the year the work of the Director has been with the National Research Council and the Sanitary Corps of the Medical Department of the Army. His work has taken him to all but two of the cantonments. In addition to this work he organized and has constantly supervised a plant for breeding white mice for the Medical Department of the Army. The present output of this plant is about 500 mice per month. The mice are used in testing for pneumonia in Army camps.

A survey of the organizations, and interviews with the leading representatives, of the Central-European peoples, Balkan states, and Baltic provinces located in New York City was started by the Director and has been continued by his assistant, Miss Mary T. Scudder. This work has been partly subsidized by the National Research Council. The information secured has been regularly supplied to the Government. The work has been extended to Pittsburgh and Chicago.

During the early part of the year a beginning was made of a study of the family history and juvenile traits of military officers. Much time was also given to reading the proofs of the book entitled "Naval Officers: Their Heredity and Development."

Dr. Oscar Riddle reports as follows:

"Since October 1917, the work with the final proofs of volume 1 of the Whitman books has been completed. It is expected that this volume will be

issued during the calendar year. The proofs of volume II of the same series of books has been carried through two galleys with the aid of Dr. Banta.

"Throughout the entire year Dr. Riddle's chief effort has been directed to the assembling of a complete account of his past seven years' study of sex in pigeons. Although this work has been carried on with the utmost speed, it was not possible to make the book ready for publication before his entrance into war service. Nearly 700 tables of data have been completed, seriated, and numbered. The outline of the entire book is complete, though a few tables of data and a textual exposition of the results are still wanting. In this account work with the common pigeons has been almost entirely omitted. The previous experience of his assistant, Miss Holmes, will, however, enable her nearly to complete similar tabulations for that large body of data, probably during the next six months.

"Three new studies have been undertaken during the present year:

"(a) The effects of quinine on the production of egg yolk and egg albumen in the pigeon. This study, carried out in collaboration with Mr. Carl E. Anderson, has shown that the known nitrogen-conserving action of quinine extends to the production of the two above-mentioned substances. Relatively less egg albumen, and yolks of smaller size, result from dosage (1 grain daily) with quinine. In this case the smaller size of the yolks (ova) is probably induced by an effect upon the nitrogen metabolism rather than upon the general metabolism, and effects upon the production of sex from these treated germs are possibly not to be expected. Because of the previously observed relation of the general metabolism to sex the data for the sexes which arise from these treated germs is being carefully studied.

"(b) The effects of urotropin on the size and developmental capacities—with particular reference to sex—have now been studied during several months and the work is still being continued. It is known that this compound breaks up in the tissues into ammonia and formaldehyde. We have demonstrated that urotropin is absorbed by the ovum. This drug, therefore, offers the possibility of affecting the general metabolism of the egg-cell during its entire growth period. The results should be reported later when both the data for yolk size and for sex are complete.

"(c) The chemical composition of the brains of ataxic (?) pigeons is being studied in collaboration with Miss Mathilda L. Koch, of the Psychiatric Institute of the New York State Hospitals. The first appearance of this disorder of the voluntary movements (in an individual hatched from a *weakened* germ) and the transmissibility of the character to the fourth generation have been reported in the Year Books of previous years. The results of our first chemical study of these brains indicate that the brains of affected individuals are chemically under-differentiated, *i. e.*, juvenile or infantile in comparison with brains of normal individuals of the same age and strain. This material offers the greatest advantages for a study of the chemical aspects of hereditary mental disease, and a further study is in progress.

"In addition to these new lines of study nearly all of the several lines of investigation conducted by us during the past seven years on the nature and reversibility of sex have been continued. These results again confirm our earlier conclusions. They have, in greater part, been incorporated into the summary of our completed studies on sex.

"Mr. Karl E. Anderson assisted our general work until May 1, 1918. He collaborated in a study of the effects of quinine on certain aspects of the physiology of reproduction in doves and pigeons. Mr. Anderson joined the Army on May 1. His present duties are with the Sanitary Corps.

"Miss Ellinor H. Behre has recently undertaken a continuation of much of the work done by former assistants and the carrying out of some further studies hitherto impossible, or possible in only a very limited way.

"During the past year Miss Mary J. Holmes has been of great and especial assistance in Dr. Riddle's chief work. She has rendered irreplaceable service in the further work with his data and manuscripts."

Dr. A. M. Banta reports as follows in regard to his researches concerning additional strains of sex intergrades in *Daphnia longispina*:

"The most interesting development of the year has been the finding of sex intergrades in additional lines of *Daphnia longispina*.

"In addition to the sex-intergrade strains of *Simocephalus verulus* and the intergrade strains of *Daphnia longispina* reported a year ago, intergrades have been found repeatedly in the plus strain of No. 768. Further, sex intergrades have occurred in the strain of No. 768 kept in a dark closet, in the minus strain of No. 768, in No. 897, and in No. 898. Of the six strains of *Daphnia longispina* reared in the laboratory during the past year, No. 899 alone has failed to yield sex intergrades.

"Two additional probable occurrences of sex intergrades are of interest in this connection: (a) In 1915, along with a few males found in two strains of *Daphnia longispina*, were a few individuals then considered gynandromorphs. They were rather weak individuals when found and failed to produce young. From descriptions I am now convinced they were intergrades. (b) R. de la Vaulx has found what he called 'androgynous females,' or gynandromorphs, in *Daphnia atkinsoni*. From this account they clearly appear to have been sex intergrades.

"These extensions of the known occurrences of sex intergrades among Cladocera indicate that a condition of sex intergradeness in Cladocera is less unusual than was at first supposed; that maleness and femaleness are even less exclusive phenomena, so far as indicated by morphological characters in Cladocera, than was believed. With the relativity of sex so emphatically shown in hybrid pigeons, in hybrid moths, and in different species of Cladocera (see report for 1917), one wonders if the relativity of sex ends with pigeons, gypsy moths, and water fleas. There seems every reason to think it does not.

"We are coming to the time when it would seem imperative to revise our notions of the fixity of sex. The clear cases of sex intergrades or sex intermediates just referred to seem no more nor less illustrations of the relativity of sex than one sees in the 'crowing hen' and the 'sitting cock' or in the masculine woman and in the man who in almost intangible physical characteristics, in speech, in dress, in tastes and habits of behavior, and in methods of thought reveals himself as lacking in something which makes for the fully equipped male and as possessing qualities ordinarily recognized as characteristics of the female.

"Further, it does not seem necessary to suppose that relativity of sex is restricted to cases in which its very conspicuousness forces itself upon our unwilling attention in opposition to our fixed conceptions of maleness and femaleness as complete, opposed, and mutually exclusive phenomena. Indeed the more reasonable supposition may be that sex is always relative; that while most sexual individuals of whatever species are prevaillingly male or prevaillingly female, every individual may have something of the other sex intermingled with the prevailing sexual characters."

As to his studies upon the selection in the sex-intergrade strains, Dr. Banta reports as follows:

"From 8 sex intergrades from the same culture-bottle (the first undoubted intergrades found in *Daphnia longispina*), 8 intergrade strains were propagated. Strains II and VII were lost. The remaining 6 strains, after having been propagated without reference to selection for two or three generations, were subjected to selection. The basis of the selection was the degree of intergradeness of the female intergrades chosen to propagate the strains. Strains I, IV, and VI were used in an attempt to make them more strongly intergrade through selection, and strains III, V, and VIII were selected to cause them, if possible, to produce more nearly normal females. In general, the selections have been somewhat effective. In most later generations the stock in the strains selected away from the intergrade characters has been moderately or only slightly intergrade, while in some cases the stock has been almost wholly normal female. In the strains selected to make them strongly intergrade the stock has usually been strongly intergrade. Environmental conditions are effectual in influencing the stock, so that at times the strains selected toward normal femaleness have been markedly intergrade, but in general there is a fairly pronounced difference between the characters of the stock in strains selected toward femaleness and in strains selected toward a more strongly intergrading condition."

Dr. Banta has attempted little direct experimentation on sex-determination since his last report, as he has been awaiting the arrival of the Bovee potentiometer which is almost indispensable to the work. He reports as follows upon the environment and sex determination in Cladocera:

"The earlier evidence, previously reported, consisted of the following:

"(a) A simultaneous occurrence of males in two strains of *Daphnia longispina* at a time when there were great numbers of males among the 'wild' *Daphnia pulex* and *Moina* sp. in the pond from which the culture water was obtained. (During almost four years of the history of the Cladocera stock in the laboratory up to that time no males had occurred.)

"(b) The ratios of the various sex forms produced in the several sex-intergrade strains are frequently contemporaneously changed—the stock as a whole (there being mothers of different ages and from different strains *but all kept on the same food*) at one time running strongly toward femaleness, *i. e.*, prevailing normal females and slightly intergrade females. At another time the distribution of the normal females, female intergrades of various degrees of maleness, male intergrades, and males is somewhat uniform. At still another time the stock runs largely toward maleness, there being an abnormally large percentage of males and male intergrades, and so few female intergrades (or normal females) that at times some of the stock is in danger of being lost from lack of females or female intergrades capable of producing young. The influence of environmental factors alone explains such changes in proportions of the female, male, and intergrade forms.

"(c) In experiments with sex control as the object the experiments have not all been successful, but males have usually appeared in smaller or larger numbers in the culture-bottles in which they were expected.

"(d) The striking 'epidemic' of males in the laboratory in May 1917, when in the preceding $5\frac{1}{2}$ years so few males had appeared in the laboratory stock, comes at a time when there were many males among the 'wild' stock in the outdoor pond from which the culture-water was obtained, and so added to the evidence that environmental influences are the causative agent for the production of males.

"The occurrence of males is more general in the culture-water now being used than in that formerly used.

"Since the epidemic of males in May 1917 we have carefully examined our discarded bottles of Cladocera for males. In all this stock males occurred but three times before May 1917. The large number of males in the indoor cultures came when the outdoor pond from which the culture-water was obtained also contained vast numbers of males among the wild stock, as is noted above.

"In the several species and in the groups within the various species having various periods of laboratory history, the occurrence of males has been remarkably consistent. In most of the groups some males have been found in every month from May 1917 to June 1918. But the point of interest lies in the relative frequency of the males in the different groups. At a time when males are relatively abundant within one species or a group, within a species they are relatively frequent in all the other groups. When males are very scarce in one group they are also scarce in the other groups.

"Curves showing the incidence of males for the various species and groups of Cladocera in the laboratory are remarkably consistent in form. Following the frequency of males in May 1917, represented by a relatively high part in the curve, in July and August there was a very low place in the curve, males occurring infrequently; then came a high point in October and November; a small drop in December; and the highest point of all in January; this was followed by a moderately low point in April and May, with a marked rise again in June.

"While these curves for the different species and groups with different laboratory history are of course not identical, their degree of similarity is very striking. When one recalls that this Cladocera stock consists of seven species, was obtained at different places, some remotely separated from where most of it was derived, and at widely different times, this remarkable close similarity of the frequency curve for male production is very striking.

"The only factors which have been consistent throughout are the environmental factors. The diverse stock has had the same food and has been subject to the same environmental conditions, varying somewhat from month to month, but for all the stock the same for any particular month. Hence it seems clear that male production is subject to environmental control."

The Cladocera stock now being used consists of the following:

Species.	Fre- quency of strains.	Origin.	No. of months in lab- oratory.	No. gen. of descent.	Species.	Fre- quency of strains.	Origin.	No. of months in lab- oratory.	No. gen. of descent.
Daphniapulex.	{ 7	Pond II	83	271-294	Simocephalus serulatus. . .	{ 2	Pond IV	37	89-123
	1	Pond II	43	156		{ 4	Lakeland, Florida.	19	58- 63
	2	Pond III	41	149-152	Muina affinis..	4	Pond III	39	223-239
	1	Pond II	39	144					
	1	W. P.	17	61	Muina macro- copa.	3	Pond III	5	27
Simocephalus vetulus.	5	W. P.	14	45- 61					
	{ 4	Pond IV	74	215-246	Muina recti- rostris.	2	Pond III	5	20- 21
	3	Pond I	72	236-241			Lakeland, Florida.	19	54- 56
	5	Pond IV	46	150-157	Macrothrix sp.	(?)			

Dr. Banta has spent much time, since Dr. Riddle entered the Army, in revising the proofs of the Whitman volumes. Nearly all of 150 pages of tables have been checked and verified by him.

The experiments with cave forms have been continued. More young have been produced in the cave and the rearing has been more successful than in any previous year. During January 1918, Dr. Banta collected material in caves near Bloomington, Mitchell, and New Albany, Indiana. The water-level in the caves was low, so that the conditions were favorable for collecting and additional living material of the species desired was obtained and shipped to Cold Spring Harbor.

Dr. Charles W. Metz reports as follows on his work with the evolution of the germ-plasm. His studies are made with a fruit fly.

"In view of the fact that I have been engaged in war work during the entire year covered by this report, the research activities in which I was formerly engaged have been greatly curtailed. The essential work of caring for the mutant stocks of *Drosophila* and the continuation of several of the experiments, however, have been efficiently managed by Dr. Alexander Weinstein in my absence.

"Although a considerable amount of data has been obtained, there has been no opportunity to work it up, and it is difficult to draw conclusions or make generalizations at this time. Consequently, the following items are intended mainly to show the general nature and trend of the results.

"Several new mutant characters have been found by Dr. Weinstein in *Drosophila virilis*, and the linkage relations of these and some of those previously discovered have been determined. These serve to enlarge the linkage groups already identified in this fly.

"The investigation of incompatibility between mutant (and apparently allelomorphic) characters in *D. virilis* has been continued. Three characters are involved in this series.

"Considerable work has been done in the way of further analyzing the group of sex-linked characters in this species and comparing it with the sex-linked group in *D. ampelophila*. A sufficiently large series of characters is now available in the sex-linked group of *virilis* to make possible a fairly accurate determination of linkage and cross-over values and a comparison of these values with those in *ampelophila*. The results continue to indicate a correspondence between the sex-chromosome constitution of the two species, although showing a specific difference in the rate of crossing over.

"In addition to these features, Dr. Weinstein has been conducting experiments on 'coincidence' of crossing over in *D. virilis*, a line of work not previously attempted with this material."

About three years ago Dr. E. C. MacDowell began experimentation on the effect of ingestion of alcohol on rats to test the view that alcohol can permanently affect the germ-plasm. During Dr. MacDowell's absence in France the work has been carried on by his assistant, Miss Vicari. The following report is submitted:

"*Relative intelligence of rats of alcoholic and non-alcoholic parentage.*—The alcoholization of the albino rats has been continued in the first generation and carried on to the second. The main work of the year has been testing the learning capacity of: (1) the offspring of alcoholic grandparents; (2) the

offspring of alcoholic parents and alcoholic grandparents; (3) the controls of each set. The alcoholized rats themselves and their controls were also trained in one problem, Watson's maze. All the other rats were given this problem plus Yerkes's trial-and-error problem.

"Some work has been done, but not sufficient to be conclusive and no generalization is offered at this time. Table I gives a comparison of the abilities of alcoholics and normals to form a habit; it also shows that in the tests of memory and association the rats of unnarcotized parentage are almost uniformly superior to rats of alcoholic parentage. This is given only as a sample of three trained generations of rats. This family of alcoholic strain represents the best and not the poorest trained family of this strain. The alcoholized rats which were the ancestors of the second and third generations received light doses of alcohol for 3 weeks from the time of weaning (28 days) and then were given heavy doses until they were fully narcotized (dead drunk). The dose of the male was 61 days and that of the female was 83 days. Data of other experiments, where the parents received a longer period of treatment and where they received a shorter period of alcoholization, have not been sufficiently collated. All the rats of the first and second generation which were started this year were given the heavy dose from the time of weaning."

"Growth and fertility of the second alcoholized generation"—The administering of alcohol has been carried on to the second generation. The growth and fertility of the first-generation alcoholized rats was considered by Dr. MacDowell in last year's report. This report gives data upon the effect of large doses of inhaled alcohol on the growth and fertility of a series of albino rats whose parents received the alcohol treatment from the time of weaning and who themselves have been subjected to the alcohol fumes from the time of weaning. The alcohol was administered daily and the rats were left in the inhalation tanks till they were in a dead stupor or could move only very feebly. Like the rats of first generation, the time required to produce a drunk stupor was from 3 to 5 hours, according to the intensity of the alcohol vapor in the tanks, the age of the individual, and the sex. Females usually became influenced by the fumes of the same intensity quicker than the males. Rats of both sexes became influenced quicker if subjected to the alcohol vapor before their daily ration than after. As a rule they were put in the tanks early in the morning before they had their bread and milk for the day. Rat biscuit was always hanging in their cages. Normal activity was regained in from 3 to 5 hours.

"In selecting material for this generation rats were used as near alike in weight as possible at the beginning of the experiment; that is, a rat that was to be alcoholized and its control were selected of the same weight and, when this was not possible, as near alike as could be, but in every case possible the heavier rat of the two was selected for the alcoholic treatment. Except for the alcoholic treatment, all the rats were given the same attention as to food, number in a cage (always one pair), and sanitary conditions. Both sets were in similar cages and placed in adjacent rows.

"Weekly weighings were made of all the rats and individual growth-curves were plotted. From these curves the weights at the ages considered in the first generation were estimated. In making these estimations allowances were made for temporary losses in weight due to food conditions and to temporary minor illness. The controls were susceptible to skin disease much more than the alcoholics. The skin of the latter was sterilized by the alcohol vapor and hence it was not subjected to vermin. In order to reduce vermin

on the controls the rats showing a tendency to develop skin trouble were dipped every two weeks in warm 1 per cent kreso dip No. 1. Having made these allowances, the estimated weights of the two groups were plotted. The average size at stated ages was found for the two groups from these estimated weights. The results are given in table 3. The initial weight was taken of both sets at 28 days old and then alcoholization was begun for the alcoholics on the same day after the first weight-reading was taken, with the exception of two individuals which were started on the forty-third day. Males alone have been considered in this report.

"The table shows that the alcoholics were about 5 grams heavier than the controls before alcoholization and that they began to show a loss in weight between 40 to 60 days old and continued to remain below the normal weight until 243 days old.

"The fertility of the second alcoholized generation is shown in table 4. This generation, like the first, is less fertile than the normals. The average size of a litter of alcoholics does not seem to be much below the norm. The average number of litters, however, born to the alcoholics is scarcely half the number born to the normals during an equal period.

"Table 5 gives the results of the fertility record of the second generation offspring (from alcoholized parents). The number of young born to the offspring of alcoholics is greater than the controls; the average size of the litter of the former is, however, smaller than the controls.

"Table 6 gives the fertility record of the third generation (from alcoholized grandparents). The same thing is true here as for the second generation (from alcoholized parents).

TABLE 1.—Results of training. Maze problem.

Alcoholized rats and their normal sibs; parents of rats in experiment 15, first generation; 3 normal and 3 alcoholized rats.

	Normal.	Alcoholized.	Result.
Training (last 12 trials):			
1. Average time per trial in seconds.....	18.05	29.00	Normals faster.
2. Average No. of "perfect trials".....	4.00	1.00	Normals better.
3. Average No. of "errors".....	1.44	2.56	Normals better.

EXPERIMENT 15.

Non-alcoholized offspring of alcoholized parents and the controls, second generation; 6 normal and 6 alcoholic rats.

	Parents.		Result.
	Normal.	Alcoholic.	
Training (last 12 trials):			
Test 1.....	11.61	16.80	Normals aster.
Test 2.....	4.33	1.25	Normals better.
Test 3.....	1.01	2.47	Normals better.
Memory (12 trials):			
Test 1.....	11.51	15.24	Normals faster.
Test 2.....	5.66	2.75	Normals better.
Test 3.....	0.91	1.78	Normals better.

EXPERIMENT 20.

Grandchildren of alcoholics—offspring from a mating in experiment 15, third generation;
5 normal and 5 alcoholized rats.

	Grandparents.		Result.
	Normal.	Alcoholic.	
Training (last 12 trials):			
Test 1.....	9.64	19.05	Normals faster.
Test 2.....	5.50	0.41	Normals better.
Test 3.....	0.62	2.84	Normals better.
Memory (12 trials):			
Test 1.....	24.00	14.55	Alcoholic off- spring faster.
Test 2.....	5.41	2.16	Normals better.
Test 3.....	1.19	1.71	Normals better.

TABLE 1.—Results of training. Multiple-choice problem.

Problem.	Experiment 15.				More success- ful group.	Experiment 20.				More success- ful group.
	Parents normal.		Parents alcoholic.			Grand- parents normal.		Grand- parents alcoholic.		
	Cor- rect.	Wrong.	Cor- rect.	Wrong.		Cor- rect	Wrong.	Cor- rect.	Wrong.	
Training:										
I.....	4.91	9.87	4.21	11.33	Normals.	6.12	7.65	3.88	12.45	Normals.
I test.....	6.05	6.65	5.75	7.98	Normals.	6.70	5.95	5.58	7.25	Normals.
II.....	3.43	15.53	3.26	17.32	Normals.	3.71	13.05	4.03	14.47	Normals. ¹
II (omitting 1st 3 days).....	3.83	12.03	3.13	14.06	Normals.	3.71	11.45	3.48	13.54	Normals.
II test.....	4.30	10.67	3.67	13.97	Normals.	3.75	13.00	3.33	13.58	Normals.
Memory (insuf- ficient data) ..	.....	.....	.....	.....	.....	4.91	9.87	3.12	15.83	Normals.

¹ The percentage of correct choices is very slightly higher in case of the normal rats.

"In problem I the right-hand door is the correct door and in problem II the left-hand door is the correct door. Problem I is immediately followed by problem II. Both problems are of the same nature and on the same apparatus. In order to form habit II, habit I must be undone. As the normals learn problem I better, they insist more than the alcoholic offspring on going to the correct door of problem I when the problem is changed. The more fixed the habit the harder it is to undo it, and this is what happens when the rats are switched off from problem I to problem II, the latter being the undoing of the former. In training a rat from one problem to a distinctly new problem, as from the maze to the trial-and-error problem, the habit is of a different nature and as a rule those that did better in the maze do better in the multiple-choice problem. For this reason the averages of problem II (omitting the first 3 days of training) are introduced.

TABLE 2.—Number of rats trained August 1917 to September 1918.

	Total.
First-generation offspring (alcoholized, 17; normal, 17).....	34
Second-generation offspring (alcoholized and from alcoholized parents, 37; from control parents, 33).....	70
Third-generation offspring (from alcoholized grandparents, 28; from control parents, 25)...	53
Third-generation offspring (from alcoholized parents and alcoholized grandparents, 9; from control parents, 10).....	19
Total.....	176

TABLE 3.—Average weights (in grams) of the second-generation alcoholized male rats compared with their normal double first cousins.

Age.	Alcoholics.		Normals.		Differences.
	No. of individuals.	Average body-weight.	No. of individuals.	Average body-weight.	Normals heavier by—
		<i>gm.</i>		<i>gm.</i>	<i>gm.</i>
30 days.....	15	57.20	16	52.65	— 4.55
40 days.....	15	83.37	16	81.72	— 1.65
60 days.....	15	129.20	16	132.94	+ 3.74
90 days.....	14	161.93	16	172.47	10.54
120 days.....	14	201.00	14	218.29	17.29
151 days.....	13	212.00	14	242.71	30.71
182 days.....	10	248.20	13	265.00	16.80
212 days.....	8	256.12	13	277.31	21.19
243 days.....	6	271.83	9	287.11	15.28

TABLE 4.—Fertility records of the second-generation alcoholized rats compared with the controls.

Matings of the alcoholics (A) and corresponding normals (N) were made at the same age and the records of births taken during equal periods.

Group.	No. of pairs.		No. of litters.		No. of young born.		Average No. in a litter.		No. weaned.		Sex ratio.	
	A	N	A	N	A	N	A	N	A	N	A	N
wss C.....	5	5	8	14	53	103	.....	.....	20	57	10/10	30/29
LHKC.....	5	4	5	7	28	45	.....	.....	8	12	6/ 2	10/ 2
Total.....	10	9	13	21	81	148	6.23	7.05	28	69	16/12	40/31

TABLE 5.—Second-generation offspring (from alcoholized parents).

Fertility record of non-alcoholic trained offspring (A) of alcoholic parents, compared with corresponding trained normals (N); matings of the two sets were made at the same age and the records of births taken during equal periods.

Group.	No. of pairs.		No. of litters.		No. of young born.		Average No. in a litter.		No. weaned.		Sex ratio.	
	A	N	A	N	A	N	A	N	A	N	A	N
WSS A.....	3	3	9	7	52	40	.....	.....	26	23	15/11	9/14
wss B.....	2	2	2	2	6	14	.....	.....	0	12	0	?
wss C.....	2	2	4	1	31	7	.....	.....	22	6	11/11	4/ 2
LHKC.....	3	3	9	5	43	32	.....	.....	25	21	13/12	13/ 8
Total.....	10	10	24	15	132	93	5.50	6.20	73	62	39/34	26/24

TABLE 6.—*Third-generation offspring, from alcoholized grandparents.*

Fertility records of non-alcoholic trained offspring (A)₂ of alcoholic grandparents compared with corresponding trained normals (N)₂. Matings of the two sets were made at the same age and records of births taken during equal periods.

Group.	No. of pairs.		No. of litters.		No. of young born.		Average No. in a litter.		No. weaned.		Sex ratio.	
	A ₂	N ₂	A ₂	N ₂	A ₂	N ₂	A ₂	N ₂	A ₂	N ₂	A ₂	N ₂
wss A.	1	1	0	3	0	20	.....	.....	0	8	0	3/ 5
wss C.	2	2	6	7	53	39	.....	.....	20	18	12/ 8	4/ 4
LH KC.	7	7	21	9	105	64	.....	.....	30	30	16/14	18/12
Total	10	10	27	19	158	123	5.85	6.47	50	56	28/22	25/21

Dr. Abert F. Blakeslee reports on his work in plant genesis at the station as follows:

"Most of my research has been devoted to breeding and selection work with the adzuki beans which we are carrying on under the auspices of the National Research Council. In addition to the lines which we have had in cultivation for several years, some 40 new lines have been secured from Dr. C. V. Piper, of the Bureau of Plant Industry of the U. S. Department of Agriculture, and have been grown under test conditions. We have about 8 acres of adzukis under cultivation at this station and in addition have distributed seed for trial to correspondents in 52 different localities. Most of these correspondents are in agricultural experiment stations. Professor Hartil, of the New York State School of Agriculture at Farmingdale, Long Island, is cooperating in the work and has grown in test plats representatives from 38 different pure lines. When the harvest records are in from our own plantings and from plantings away from the Station, we shall be in better position to judge of the adaptability of the species to cultural conditions in this country.

"Adzuki beans seem to be immune to anthracnose, a disease destructive of the navy bean; but unfortunately certain lines at least seem susceptible to bean 'mosaic,' which is common in New York State on various races of *Phaseolus vulgaris*. It is possible that immune races of the adzukis may be discovered. A disease, probably due to the fungus *Fusarium*, brought in perhaps by soya beans, with which we have surrounded our breeding-plats as a protection against rabbits, has caused trouble in parts of the garden.

"Disorganization of the gardening staff due to the war has somewhat handicapped the work of the department. Mr. Avery was called by the selective draft late last year. Mr. Farnum served as temporary gardener for about 3 months and Miss Minns has been acting gardener during the summer. While both have carried on their individual work satisfactorily, it has necessarily taken some time for each to become familiar with the special crop under cultivation. Mr. Welch, my laboratory assistant, was taken by the draft early in July and Miss Conover has been engaged to fill his place.

"In addition to the disorganization of the work due to the changes in assistants, difficulties in growing and hybridizing the adzuki beans under glass have been encountered and much time has been lost in consequence. It has been discovered that they will not thrive in the greenhouse during the

winter, apparently on account of lack of sufficient illumination. It is hoped that in the new greenhouse, which is considerably lighter than the old ones, it will be possible to get two generations a year by growing them under glass in early spring and autumn, when more sunlight is available than in midwinter.

"While the work on the adzuki beans has been primarily a practical problem with relatively little theoretical interest, some study is being made of the inheritance of seed-color characters that may be of genetic interest in connection with an attempt to obtain a strain that will not only be highly prolific but also satisfy the market requirements in respect to seed appearance.

"A mutation with unifoliate leaves has appeared in one of our inbred lines. All the other varieties of adzuki investigated have exclusively trifoliate leaves, and the character is so conspicuous that it could hardly have occurred in pedigree cultures without having been noticed.

"If the adzuki bean is to be of any great value as a human food it must not only be satisfactory from the cultural standpoint but must be palatable, readily prepared for the table, and of high nutritional value. Dr. Langworthy, of the Home Economics Office, United States Department of Agriculture, has kindly had investigated for us the cooking qualities of the adzuki beans and has prepared a series of recipes for them both in the form of bean meal and the whole bean. He reports that 'all preparations from adzuki beans have a nutty flavor and are very palatable.' He further writes that he thinks it will 'be well to continue the study of adzuki beans with reference to their more general use.' Miss Florence Willard, head of the domestic science department in the Washington Irving High School in New York City, has also tested the adzukis extensively and reports favorably upon them. They seem to cook up in about half the time necessary for the navy beans, though if cooked too long they tend to lose their individuality.

"Dr. C. O. Johns, of the United States Bureau of Chemistry, is carrying on feeding experiments with rats and will undertake an investigation of the proteins of the adzuki beans. Dr. E. V. McCollum has promised to investigate the fat and water soluble unknowns in the seeds. An economic plant-breeding problem may not be solved quickly. Consequently, it may be some years before it is possible to decide upon the value of the adzuki bean as a food crop for this country.

"On account of the work with the adzuki beans, no new problems have been undertaken. It has been possible, however, to keep under way some of the investigations already undertaken.

"Work on rudbeckias has been discontinued for the present, although seed obtained from last year's crosses are ready for planting.

"Planting this year of F_2 seed show that the dwarf portulaca reported last year is a simple Mendelian recessive; that the reversionary dominant branches which the dwarf plants occasionally produce are heterozygous and when selfed throw 3 normals to 1 dwarf; that cuttings from these reverting branches, when kept growing for a couple of years, show no increased tendency to throw normals. A large number of crosses of portulacas made last year in a study of the varied color characters of the flowers have not been planted.

"A peculiarity in the fragrance of two verbena plants has been discovered. The flowers of plant A are fragrant to me and to two-thirds of the members of the station tested, while the flowers of plant B are not fragrant to us. The reverse condition is true of my former assistant, Mr. Avery. To him and to about one-third of the members of the station the flowers of B are fragrant, while those of A are not. Obviously the phenomenon is caused by a difference in the sensory organs of the two groups of people tested.

"In the jimson weed (*Datura*) it has been possible to further test the inheritance of the 'globe' mutant, since the mutant can be recognized in the seed-pans. Over 5,000 seedlings have been grown this winter in the test, about equally distributed between selfs, globes $\times$ normals, and normals $\times$ globes. When the globes are selfed and the globes as females are crossed with normals about the same results are obtained in the offspring, *i e.*, approximately 3 normals to 1 globe; while normals crossed with globes as male parents throw about 38 normals to 1 globe. The mutant complex therefore seems to be but slightly transmitted through the male parent. It is transmitted through the female parent either when selfed or when crossed with a normal, but appears in only about a quarter of the offspring. The mutant has been selfed for five generations, but as yet it seems impossible to obtain a pure race of globes. The mutants 'cocklebur,' 'poinsettia,' and others seem to be inherited in much the same manner, although extensive tests have not been made of other mutants than the globe.

"Last year a 'quercina' disease of the jimson weed was reported which causes a laceration of the leaves, splitting of lobes of the corolla, and a suppression of spines on the capsules. This disease was found to be transmitted by grafting, but not by contact nor by inoculation. Another disease somewhat similar in its effects has been discovered. It causes a more pronounced malformation of the leaves (often reducing them to mere midribs), induces a suppression of spines on the capsules and the production of distorted accessory carpels in the flowers. It is readily propagated by contact of diseased leaves with normal plants. It also differs from the 'quercina' disease in that it is not carried by the seed.

"Several years ago at Storrs, Connecticut, a study was begun upon the inheritance of the weeping habit of a number of trees. Last season a single tree from a cross between Tee's weeping mulberry and the common white mulberry came into flower and was back-crossed with the weeping variety. Some hundred seedlings from this cross are now growing in the garden and, while definite counts have not been made as yet, the erect individuals and those spreading prostrate like a vine over the ground are approximately in equal numbers. From the results of this back-cross the weeping habit in the mulberry would seem to be a simple Mendelian recessive. Seedlings from *inter se* crosses made between F_2 plants this spring are now growing in the greenhouse and may be expected to show 3:1 ratios in habit characters by next summer.

"In cooperation with Dr. Harris and with the Poultry Department of the Storrs Agricultural Experiment Station, we have published a bulletin on pigmentation and other criteria for the selection of laying hens, which embodies our results already reported, together with new data. Our results seem to be proving of practical value to poultrymen in their attempt to cull out the unproductive birds from their flocks and thus to reduce their feed bills."

Dr. J. Arthur Harris has continued his work in various lines and reports as follows:

"*Investigations of osmotic concentration of vegetable saps.*—These studies have been continued along lines indicated in previous reports. A memoir on the plants of the Jamaican coastal deserts has been published in cooperation with Mr. John V. Lawrence. The results show excellent agreement with conclusions already drawn from investigations of the Arizona deserts. The results of a first study of desert Loranthaceæ parasitic on various hosts have also appeared. The desert Loranthaceæ, like the desert host-trees, show a far higher osmotic concentration than those studied in the Jamaican montane

rain-forest. In general the tissue fluids of the parasite show a higher osmotic concentration than do those of the leaf-tissue of the host tree."

"*Miscellaneous studies of variation and correlation in plants.*—A study of the distribution of abnormalities in the inflorescence of *Spiræa* and an investigation of the relationship between the number of stamens and pistils in the flowers of *Ficaria* have been published."

"*Studies on variation, correlation, and selective death-rate in garden beans.*—These investigations have been continued along lines indicated in earlier reports. A general summary is now being prepared of studies on the influence of the depauperization of the ascendants, on the characteristics of the descendants, of the correlation between the weight of the seed planted and the characters of the plant produced, and of the correlation between the characters of the plant and the characters of the pods and seeds which it bears, and of some other problems.

"In the teratological phases of the work, a paper on the correlation of the characters of the second and third node has been published in cooperation with Mr. Avery. A detailed investigation of the green weight, dry weight, and tissue-water content of the leaves of the seedlings showing the slightest structural variation has been published. A similar investigation of seedlings which are trimerous at the first and second nodes has also been completed. These studies show that variations are not merely structural, but that physiological differences are associated with the structural variations. These results will eventually be considered in relation to the problems of the selective death-rate."

"*Miscellaneous studies in statistical theory.*—As in previous years, considerable attention has of necessity been given to statistical methods. A paper on the correlation between a component and between the sum of two or more components and the sum of the remaining components of a variable, and another paper on further applications of a coefficient measuring the correlation between a variable and the deviation of a dependent variable from its probable value have been published. The formulæ developed in both of these papers have had or are shortly to have application in the solution of problems of economic importance."

"*Variation, correlation, and probable errors of plot tests.*—If genetic work is to be of importance in practical agriculture it must not result merely in the formulation of the laws by which breeds of animals and plants showing new characters or new combinations of characters may be secured, but it must provide the means by which these strains, breeds, or varieties may be tested with respect to their economic performance. If such means of critically testing the various strains are not provided, the multiplication of forms can result only in confusion, and not in progress. The plot test has been in the past and is at present the chief method of determining the relative values of a series of strains. Notwithstanding the enormous economic importance of such work and the great annual financial outlay in the making of such tests, our knowledge of the theory of plot tests is far from satisfactory.

"During the past several years various problems of plot tests have been considered at this Station. At present the work is being continued with the cooperation of the Office of Western Irrigation Agriculture and the Office of Dry Land Farming of the United States Department of Agriculture."

"*Biometric studies on egg-production.*—The studies on egg-production outlined in earlier reports have been continued and extended on data furnished by the Poultry Department of the Connecticut Agricultural College and Agricultural Experimental Station at Storrs. In connection with Messrs. Blakeslee, Kirkpatrick, and Warner an experiment station bulletin has been

published giving more practical results of biometric studies on the methods of selecting laying hens by the use of pigmentation and other somatic characters. While the somatic criteria employed permit the selection of the birds which are laying or have recently been laying in the latter parts of the year with a rather high degree of accuracy, they have not as yet been shown to be suitable for the early prediction of future production. The foundation for such prediction was laid in a paper on the correlation between egg-production during various periods of the year, published in *Genetics* for January 1918. At present studies designed to make possible the more accurate prediction of the future production of birds from their earlier months records are under way. The solution of this problem seems to have considerable economic significance at a time when the conservation of grain feed (by the early elimination of birds which would if kept make the poorest records) is a matter of especial importance."

"Cooperative work on human metabolism.—During the past two years a biometric study of the Nutrition Laboratory data on basal metabolism in normal men, women, and new-born infants has been under way in cooperation with Dr. Benedict. This is now completed and is to be issued as publication 279 of the Carnegie Institution of Washington."

EUGENICS RECORD OFFICE.

C. B. DAVENPORT, DIRECTOR.

This institution, which is located at Cold Spring Harbor, Long Island, New York, came into the control of the Carnegie Institution of Washington on January 1, 1918. It was organized by the present director October 1, 1910, with funds given him for this purpose by Mrs. E. H. Harriman. This report will present a brief review of the work of this office from its establishment to January 1, 1918, and will give a more detailed account of its activities from that date to October 1, 1918. Since its establishment the chief activities of this office have been:

1. *To serve eugenical interests in the capacity of repository and clearing, house.* In order to provide data adequate to making eugenical studies, it was found necessary to secure a wide interest on the part of the better families of the country in their own pedigrees, and on the part of custodial institutions in securing pedigrees of the socially inadequate strains. Efforts in this direction have been successful, until now many genealogists and biographers are not only seeking to give their family-history compilations a more biological aspect, but are anxious to have a copy of their studies in the archives of this office, while many superintendents of custodial institutions look upon the Eugenics Record Office as a very useful central bureau for depositing records and seeking eugenical data. As a clearing-house, the public may make inquiries and be informed concerning (a) the methods of making eugenical records, (b) what studies have been made upon certain families, (c) eugenical activities of a given institution or section of the country, (d) the nature of the method of inheritance of a given natural trait, so far as the knowledge of such exists, (e) the analysis of fact, and records with the view to determining their eugenical meanings (f) existing laws bearing upon eugenics, and (g) outlining and advising concerning special problems for eugenical study. The purpose of these activities is to coordinate the interests and investigations of this new science along lines which will yield records and analyses of the greatest eugenical value.

2. *To build up an analytical index of the inborn traits of American families.* The purpose of the archives department is to catalogue and index all records which come into the possession of the Eugenics Record Office. Up to January 1, 1918, there had been opened 534,625 cards (each card contains spaces for 40 entries), which index the individuals described in the records in the archives on the basis of surname, natural trait, and geographical locality. In this work human traits are classified on an indefinitely expansible system, the first synopsis of classification being: 0, general traits; 1, integument-

tary system; 2, skeletal and muscular systems; 3, nervous system and psychopathic traits; 4, mental traits and movements; 5, sense organs; 6, nutritive system; 7, respiratory system; 8, excretory and reproductive systems. As these cards accumulate they furnish information concerning the location of data needed for studying the nature of the inheritance of specific traits, for tracing their descent and recombination in given pedigrees, and for demographic and statistical studies.

3. *To train field workers to gather data of eugenical import.* Cooperating with the Biological Laboratory of the Brooklyn Institute of Arts and Sciences, of which laboratory the Director of the Eugenics Record Office is also director, there has been given for six weeks, during July and August in each year, beginning in 1910, at the Eugenics Record Office, a training course for field workers in eugenics. This work has been under the direct supervision of the Director, assisted by Dr. Harry H. Laughlin, superintendent of the Eugenics Record Office. Enrollment in this course has been as follows: 14 in 1910, 25 in 1911, 21 in 1912, 28 in 1913, 20 in 1914, 13 in 1915, 20 in 1916, 13 in 1917; total 171.

The course of instruction comprises 25 lectures on human heredity and eugenics, with special reference to conduct; also daily laboratory work on the following topics: Charting family pedigrees; constructing and using mechanical, chemical, and statistical models for illustrating the principles of heredity; tracing the descent and recombination of human traits in actual pedigrees; analyzing such pedigrees in the light of the existing knowledge of heredity; analyzing statistics given in institutional and federal reports; statistical studies on variation in plants and animals; studies in the elements of biometry; physical and mental measurements in man, with special reference to the Binet and Yerkes-Bridges tests. Clinical studies are made at institutions for various types of the socially inadequate. Field trips are made for the purpose of securing family pedigree records at first hand.

The Eugenics Record Office keeps in close touch with all graduates of this course, most of whom subsequently are actively engaged professionally in eugenical work, many of them becoming field investigators for this office and for State institutions.

4. *To maintain a field force actually engaged in gathering eugenical data.* The special field studies which have been carried on by the Eugenics Record Office independently have included investigations of the "Ishmael" tribe of Indiana, the Amish sect of Pennsylvania, albino families of Massachusetts, the "Nam" family of New York, the "Jukes" of New York, skin-color studies in New Orleans and in the islands of Bermuda and Jamaica, Huntington's chorea in New York and Connecticut, pellagra in South Carolina, consanguinity in Outer Long Island, Maine, the "Hill Folk" in Connecticut, community studies in Woodbury (Connecticut), sterilized men in the Jeffersonville

(Indiana) Reformatory, Indian hybrids (Elbow Woods, North Dakota), and human stature and hare-lip studies in many localities.

5. *To cooperate with other institutions and with persons concerned with eugenical study.* Besides the field studies of the office, undertaken independently by the members of its staff, there is a second type of field investigation which has yielded rich returns, these latter studies being conducted jointly by this office and other institutions. The collaborating institutions have, for the most part, been hospitals for the insane and institutions for the delinquent and the feeble-minded. There have been 47 workers placed under the cooperative plan. Under this scheme the Eugenics Record Office trains the worker, pays the salary, provides the field worker's outfit, and criticizes the work; the collaborating institution provides the maintenance and traveling-expense money and has direct supervision over the work, indicating the individual cases in the institution whose family histories shall be worked out from the eugenical point of view by the field worker. The reports are made in duplicate, one copy being retained by the collaborating institution and the second filed with the Eugenics Record Office. These workers continue under the joint basis for one year, at the expiration of which time the collaborating institution, having learned the value of such work, is expected to, and as a matter of fact generally does, provide for such investigation as a part of its permanent work, independently of the support of the Eugenics Record Office. The work has proven of value because by it not only have new and permanent centers of eugenical study been opened, but the institutions which continue studies of family history independently have quite uniformly continued to deposit duplicate copies of their studies in the files of the Eugenics Record Office, thus greatly enriching our archives.

Before coming into the control of the Carnegie Institution of Washington, there had been accumulated 51,851 pages of first-hand manuscript data prepared by the workers of this office.

6. *To investigate the matter of the inheritance of specific human traits.* The field studies above referred to have a double purpose: (1) to provide a permanent record of the family distribution of traits, with the view to predicting their transmission in true pedigree fashion; (2) to provide data for statistical analyses and for further investigations into the manner of the hereditary transmission of given qualities. In order to advance the collection of pedigree records adequate to these studies the following schedules were prepared:

A. General biological pedigree investigations.

1. Record of family traits, a brief general record.
2. Index to germ-plasm, two sets of the record of family traits to be filled out for the families of persons contemplating marrying each other, in order to judge of the eugenical fitness of the proposed marriage.
3. Genealogical cards—the so-called plan I, for a loose-leaf, indefinitely expandible family analysis more detailed than is called for by the record of family traits.

A. General biological pedigree investigations—*Continued.*

4. Family distribution of personal traits, the so-called plan II; also an indefinitely expansible loose-leaf system, of which the individual analysis card is the unit. This is the most detailed and valuable and also the most difficult of all the schedules. It should not be asked for until the record of family traits has been successfully filled out.

B. Short schedules for special-trait pedigree records: (1) Musical talent; (2) mathematical ability; (3) tuberculosis; (4) hare-lip and cleft-palate; (5) hair form, hair and eye color, and complexion; (6) stature; (7) physical measurement record; (8) twins; (9) special trait card. These schedules are sent free in duplicate to such persons as will undertake to fill them out and, after retaining one copy for their own family archives, will file the other with the Eugenics Record Office.

The record of family traits is based upon Galton's original outline. Of these, 2,618 had been secured by the volunteer cooperation on the part of the families described. Of the schedules later prepared, 15 of the family distribution of personal traits were on hand; there were 54 of the records called "index to germ-plasm"; 46 individual analysis cards; 576 special schedules on stature; 646 eye, hair, and skin color schedules; and 303 other special-trait records, including musical, mathematical, tuberculosis, epilepsy, and deafness. There were 5,375 cards indexed in the hare-lip study.

A library of 3,093 books, besides numerous institution reports, has been accumulated.

7. *To investigate other eugenical factors, such as mate selection, differential fecundity, differential survival, and differential migration:* These studies are demographical and sociological in nature and their development will follow rather than precede those phases of eugenical investigation bearing more directly upon the phenomena of inheritance. A study of 1,054 unselected subnormal families, described by field workers, contrasted with a similar study of 701 families from our better American stock, showed that in the subnormal families the average number of children per family was 4.4, while in the normal families the average was 4.6; that the infant mortality (those dying under 3 years of age, including stillbirths) was 17.4 in the subnormal and 8.3 in the normal.

8. *To advise concerning the eugenical fitness of proposed marriages.* This is a service which is being used with continually growing frequency. Most inquiries grow out of two situations: first, contemplated cousin matings; second, the marriage of persons in one or both of whose families there is a neuropathic taint. Persons making request for advice along these lines are always required to prepare family-history studies in accordance with instructions given by the office. Eugenical advice is then rendered in accordance with the limitations set by the facts presented and the existing knowledge of the inheritance of traits. The pedigrees submitted are added to the archives of the office.

9. *To publish the result of researches.* Up to January 1, 1918, there had been published 18 bulletins, 2 memoirs, and 1 report, as follows:

BULLETINS.

1. Heredity of feeble-mindedness. Henry H. Goddard. April 1911, 140 p., 15 pedigree charts.
2. The study of human heredity. C. B. Davenport, H. H. Laughlin, D. F. Weeks, H. H. Goddard, E. R. Johnstone. May 1911, 17 pp., 6 plates.
3. Preliminary report of a study of heredity in insanity in the light of the Mendelian laws. Gertrude L. Cannon and A. J. Rosanoff. May 1911, 11 pp., 12 charts.
4. A first study of inheritance in epilepsy. Charles B. Davenport and David F. Weeks. Nov. 1911, 30 pp., 33 charts, 11 tables.
5. A study of heredity of insanity in the light of the Mendelian theory. A. J. Rosanoff and Florence I. Orr. Oct. 1911, 43 pp., 73 charts, 2 tables.
6. The trait book. Charles B. Davenport. Feb. 1912, 52 pp., 1 colored plate, 1 figure.
7. The family-history book. Charles B. Davenport and others. Sept. 1912, 101 pp., 16 figures, and 5 plates.
8. Some problems in the study of heredity in mental diseases. Henry A. Cotton. Aug. 1913, 59 pp., 9 figures, 5 folded charts.
9. State laws limiting marriage selection examined in the light of eugenics. Charles B. Davenport. June 1913. 66 pp., 2 charts, and 3 tables.
10. Studies of the committee on sterilization, Harry H. Laughlin, secretary.
 - (a) The scope of the committee's work. 64 pp., charts and tables.
 - (b) The legal, legislative, and administrative aspects of sterilization. 150 pp., 4 charts, 13 tables, 1 map.
11. Reply to criticism of recent American work by Dr. Heron, of the Galton laboratory. C. B. Davenport and A. J. Rosanoff. Feb. 1914, 43 pp.
12. The feebly inhibited: Violent temper and its inheritance. Charles B. Davenport. Sept. 1915, 36 pp., 11 charts, and 8 tables.
13. How to make a eugenical family study. Charles B. Davenport and Harry H. Laughlin. June 1915, 35 pp., 4 charts, and 2 tables.
14. Hereditary fragility of bone (*fragilitas osseus*, osteopsathyrosis). H. S. Conrad and C. B. Davenport. Nov. 1915, 31 pp., 35 figures, 8 pp. bibliography.
15. Dack family. Mrs. Anna Wendt Finlayson. May 1916, 42 pp., 1 chart.
16. The hereditary factor of pellagra. C. B. Davenport. A study of the heredity of pellagra in Spartanburg County, South Carolina, Dr. E. B. Muncey. July 1916, 75 pp., 28 figures, and 8 tables.
17. Huntington's chorea in relation to heredity and eugenics. C. B. Davenport, based on field-notes made by Dr. E. B. Muncey. Oct. 1916, 29 pp., 3 tables, and 1 map.
18. Inheritance of stature. C. B. Davenport. July 1917, 77 pp., 19 text figures, and 33 tables.
19. Report of the first twenty-seven months' work of the eugenics record office. Harry H. Laughlin. July 1913, 32 pp., 9 figures, 1 map, and 1 chart.

MEMOIRS.

1. The Hill folk. Report on a rural community of hereditary defectives. Florence H. Danielson and C. B. Davenport. Aug. 1913, 3 folded charts and 4 text figures, 56 pp. quarto.
2. The Nam family. A study in cacogenics. Arthur H. Estabrook and Charles B. Davenport. Aug. 1912, 4 charts, 4 text figures, 85 pp. quarto.

Besides the above, the following books published elsewhere were based largely upon data furnished by the Eugenics Record Office:

1. Eugenics. Charles B. Davenport. 35 pp., 4 plates. Pub. by Y. M. C. A. Health League.
2. Heredity in relation to eugenics. Charles B. Davenport. Octavo, 298 pp., 175 illustrations and diagrams and plates. Pub. by Henry Holt & Company.
3. Heredity of skin-color in negro-white crosses. Charles B. Davenport. Octavo, 106 pp., 4 plates. Carnegie Inst. Wash. Pub. No. 188.
4. The feebly inhibited: II. Nomadism, or the wandering impulse with special reference to heredity. III. Inheritance of temperament. Charles B. Davenport. Octavo, 158 pp., 89 figs. Carnegie Inst. Wash. Pub. No. 236.
5. The Jukes in 1915. Arthur H. Estabrook. Quarto, 85 pp., 28 charts, 18 tables. Carnegie Inst. Wash. Pub. No. 240.
6. Naval officers: Heredity and development, Charles B. Davenport and Mary T. Scudder. Octavo. Carnegie Inst. Wash. Pub. No. 259.

WAR SERVICE.

From a period antedating our declaration of war with Germany until the present time, Dr. H. H. Laughlin, superintendent, who had

had previous military training, gave military drill, not only to members of the Eugenics Record Office and the Station for Experimental Evolution, but also to men in the nearby village of Cold Spring Harbor. He has served as captain of the company and is commissioned by the State, which soon recognized his company as part of the State defense. In consequence of the training received, those who have gone into the service of the United States Army or Navy have been of especial value in that service and have soon become officers.

During the year Dr. Arthur H. Estabrook, field investigator, was commissioned as first lieutenant and detailed on the staff of Major R. M. Yerkes, at Fort Oglethorpe, Georgia, engaged in weeding out mental defectives from the army. Mr. Tracy E. Tuthill, archivist, has been commissioned first lieutenant in the Infantry Reserve Corps, Plattsburg Barracks. Mr. Leslie E. Peckham, clerk in the administrative department, has joined the colors as private in the training camp at Yaphank, New York.

EUGENICS RESEARCH ASSOCIATION.

On June 21 and 22 the sixth annual meeting of the Eugenics Research Association was held at the Eugenics Record Office. This society, now affiliated with the American Association for the Advancement of Science, is the outgrowth of the field studies of this office, in collaboration with the growing body of independent investigators. There are approximately 250 persons in the United States now intimately enough acquainted with the purpose of eugenical studies, or engaging professionally in them, who are eligible to membership in this society. Of this number 115 are actually associated with it. The president for the year 1918-19 is Mr. Madison Grant.

TRAINING COURSE FOR FIELD WORKERS.

The training course for field workers began July 3 and ended August 13. It was composed of 8 students, thus bringing the total number of persons trained in the course up to 179.

THE EUGENICAL NEWS

The Eugenical News is published monthly (octavo, 8 pp.) by the Eugenics Record Office. Its first number appeared January 1916. At present 1,000 copies of each issue are printed. This periodical serves a number of purposes: first, to keep the newly organized body of eugenical workers in touch with each other; second, to review matters of eugenical interest which appear currently in the scientific magazines; and third, to review and analyze current biographies in the light of the relation between natural traits and juvenile promise on the one hand, and adult performance on the other.

Summary of material added to the archives during the current nine months.

Index cards.....	75,290	Manuscript material— <i>continued</i> .	
Persons-index.....	350	Genealogical data cards.....	146
Manuscript material:		Biographies.....	44
Field reports.....	1,326 pp.	Collective biographies.....	5
Musical schedules.....	300 pp.	Biographical pamphlets.....	2
Special traits.....	322 pp.	Genealogies.....	8
Records of family traits.....	200	Genealogical pamphlets.....	2
Family distribution of personal traits.....	5	Town histories.....	3
Individual analysis cards.....	34	Church histories.....	3
		Vital records.....	9

FIELD STUDIES—COOPERATIVE PLAN.

Miss Bertha Pfister was employed as field worker with the Eastern Pennsylvania State Institution for the Feeble-Minded and Epileptic, Spring City, Pennsylvania.

Miss Clara P. Pond conducted the field investigations for the psychiatric clinic in collaboration with Sing Sing Prison, Ossining, New York, until this clinic was closed for the duration of the war, July 15.

Miss Ethel H. Thayer continued her work at Letchworth Village, Thiells, New York.

Miss Mildred S. Covert carried out cooperative field studies with the State Mental Hospital, Provo, Utah, until April 30.

For the forthcoming year negotiations have been completed whereby this cooperative work will be carried on at (1) Foxborough State Hospital for Inebriates, Foxborough, Massachusetts; (2) Central Islip State Hospital, Central Islip, New York.

INDEPENDENT FIELD INVESTIGATIONS.

Dr. A. H. Estabrook, until called to the colors, continued his investigations on the Tribe of Ishmael in Indiana. Since this time the work has been kept alive through the activities of Mrs. Estabrook, who is able to give a considerable part of her time to the study.

Dr. Howard J. Banker continued his special family-history studies in the Genealogical Library, New York City.

Dr. Elizabeth B. Muncey continued special pedigree studies at Cold Spring Harbor and at Washington, D. C.

On October 1, 1917, Miss Louise A. Nelson succeeded Lieut. Tracy E. Tuthill as archivist of the manuscript records.

On November 15, 1917, the Director organized a department of printed archives and placed Dr. Wilhelmine E. Key in charge. She has indexed 68 genealogies and town histories.

CLIPPINGS.

Clippings bearing on eugenics, with special reference to biographical and family-history data, are accumulated and indexed by this office. The 5 by 8 inch manila cards on which these clippings are pasted are duly indexed in the files of the office.

STERILIZATION STUDIES.

The designation "committee to study and investigate the best practical means for cutting off the defective germ-plasm in the human population" of the old American Breeders Association, which prepared Bulletins Nos. 10a and 10b of the Eugenics Record Office, has been

changed to "committee on cacogenic control" of the Eugenics Research Association. Mr. Bleecker Van Wagenen remains as chairman and Dr. H. H. Laughlin as secretary. During the year the society secured and abstracted the case histories of 777 persons who were sterilized under the several eugenical sterilization State statutes, these being a practically complete record of such operations legally performed. Records of the new sterilization laws of Iowa, Nebraska, California Oregon, Kansas, and South Dakota were secured and annotated for publication. Similarly, accounts of the litigation growing out of the sterilization laws of Iowa, New Jersey, Michigan, New York, Washington, and Nevada were compiled.

PUBLICATIONS.

- Davenport, Charles B., and Samuel A. Preiser. Neurofibromatosis, *Amer. Jour. of Med. Sci.* (Sept. 1918).
———, and Mary T. Scudder, *Naval officers: Their heredity and development*, Carnegie Inst. Wash. Pub. No. 259.
Laughlin, Harry H. The modification of the 9:3:3:1 ratio, *Amer. Nat.*, 12 pp., 11 diag. (June, July, 1918).
———. Durations of the several mitotic stages in the root-tip of the onion, Carnegie Inst. Wash. Pub. No. 265.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

The activities of the Geophysical Laboratory for the past year have been confined to the development of war problems in direct association with the War Industries Board, the Bureau of Mines, and the Nitrate Division of the Bureau of Ordnance of the War Department. All other research work has been laid aside.

Some account of our work on optical glass was given in the annual report of this department for the year 1917, but for reasons of expediency its further details must await a more opportune time of publication. It has also been deemed unwise, for military reasons, even to indicate at this time the other problems upon which the laboratory is now engaged.

PUBLICATIONS.

A number of publications are reviewed in the paragraphs which follow, being for the most part the records of researches in progress at the time of the entry of the United States into the war. A portion of this work has been brought to a tentative or final conclusion as opportunity offered and has been published during the current year.

- (1) Heat convection in air, and Newton's law of cooling. Walter P. White. *Phys. Rev.*, 10, 743-755 (1917).

In very narrow layers of air between vertical surfaces at different temperatures the convection currents, in the main, flow up one side and down the other, with eddyless (stream-line) motion. It follows that these currents transport heat to or from the surfaces only when they turn and flow horizontally, from which fact it follows, in turn, that the convective heat transfer is independent of the height of the surface. It is, according to the laws of eddyless flow, proportional to the square of the temperature difference and to the cube of the distance between the surfaces. As the flow becomes more rapid (*e.g.*, for a 20° difference and a distance of 1.2 cm.), turbulence enters, and the above relations begin to change. The change is apparently gradual, and the present results, as well as some obtained by other experimenters, are rather negative as to the possibility of expressing the flow simply for the corresponding range of conditions, which covers those most usual in calorimetry. The results, however, are sufficient to serve as a practical guide in calorimeter designing. For the dimensions tested, the transmission of heat by convection in horizontal layers was a little over twice that in vertical.

- (2) A silica-glass mercury still. J. C. Hostetter and R. B. Sosman. *J. Wash. Acad. Sci.*, 8, 11-15 (1918).

A description, with specifications and dimensional drawing, of a vacuum mercury-still made of fused silica ("quartz glass") and heated electrically. It has the advantage over ordinary glass stills of avoiding the danger of collapse due to overheating.

*Situated in Washington, D. C.

- (3) The laws of chemical equilibrium. Erskine D. Williamson and George W. Morey. J. Am. Chem. Soc., 40, 49-59 (1918).

In examining the complicated chemical systems which present themselves in the study of geophysical problems it is found that the approximate formulas used for dilute solutions break down and prove worse than useless even for qualitative application. The monumental work which the genius of Willard Gibbs evolved in 1876 remains the safest guide and that to which reference must necessarily be made. The extremely mathematical setting with which he surrounds his arguments has militated against the general use of his results by chemists, and a consequence of this is that much ink has been spilled in proving, by roundabout and far from rigid methods, theorems which are either explicitly stated by Gibbs or are so readily deducible from his equations as to be implicit in his work. This paper has therefore been written as an attempt to popularize, in so far as such a term can be used in this connection, the derivation of the fundamental equations and to deduce from them such additional formulas as are found necessary for the derivation of the theorems bearing on the chemical side of equilibrium. The applications of these theorems to actual cases will be discussed in later papers. (See Abstract No. 4.)

- (4) Pressure-temperature curves in monovariant systems. George W. Morey and Erskine D. Williamson. J. Am. Chem. Soc., 40, 59-84 (1918).

Willard Gibbs, in his paper "On the equilibrium of heterogeneous substances," derives the following expression (equation 129) giving the relation between the variations in pressure and temperature in monovariant systems:

$$\frac{dP}{dT} = \frac{\begin{vmatrix} \eta_1 & m_1' & m_1'' & \dots & \dots & m_1^n \\ \eta_2 & m_2' & m_2'' & \dots & \dots & m_2^n \\ \eta_3 & m_3' & m_3'' & \dots & \dots & m_3^n \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \eta_{n+1} & m_{n+1}' & m_{n+1}'' & \dots & \dots & m_{n+1}^n \end{vmatrix}}{\begin{vmatrix} v_1 & m_1' & m_1'' & \dots & \dots & m_1^n \\ v_2 & m_2' & m_2'' & \dots & \dots & m_2^n \\ v_3 & m_3' & m_3'' & \dots & \dots & m_3^n \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ v_{n+1} & m_{n+1}' & m_{n+1}'' & \dots & \dots & m_{n+1}^n \end{vmatrix}}$$

From the form of this equation, it follows that whenever there is a linear relation between the composition of n or fewer phases in a system of n components, the equation representing the relation between the variations of pressure and temperature in a monovariant equilibrium, *i. e.*, an equilibrium between $n+1$ phases, reduces to an expression which contains only terms relating to the phases between which the above-mentioned linear relation holds. From this fact may be deduced the following theorem:

Whenever, in a system of n components, a linear relation exists between the composition of n or fewer phases, the pressure-temperature curves of all monovariant equilibria containing these phases coincide. When all the reacting phases are of constant composition, the curves will coincide throughout their course; when the composition of some or all of the phases is variable, and they only casually have such a composition that the above linear relation is possible, then the curves are tangent.

The above theorem relates only to the slope of the P - T curves which pass through the invariant point. Of necessity, the portion of the P - T curve lying on one side of the invariant point represents stable conditions, the portion on the other side metastable conditions. The above theorem does not tell us on which side of the invariant point the equilibrium we are considering is stable. To answer this question absolutely requires a knowledge of the volume and entropy changes which take place when the reaction proceeds, but without such knowledge the following generalizations may be made. The P - T curves of condensed systems, *i. e.*, systems containing only solid and liquid phases, are almost vertical, and go from the invariant point to regions of higher pressure and (usually) higher temperature. The P - T curves of systems composed solely of solid and vapor phases, *e. g.*, dissociation pressure curves, go from the invariant point to regions of lower temperature and pressure. Also, from the fundamental conditions of stability laid down by Gibbs, the following theorem can be proved:

*When two adjoining P - T curves coincide, due to a linear relation being possible between the compositions of the n phases common to both the monovariant equilibria, *i. e.*, to these n phases lying on the one-fold (n), whose position is determined by the above linear relation, these equilibria are stable in the same direction from the invariant point, *i. e.*, their stable portions coincide, when the other two phases lie on opposite sides of the one-fold (n), and vice versa.*

By "the other two phases" is meant the phases, one in each of the monovariant equilibria, which do not lie on the one-fold (n).

The above considerations make possible (with no other knowledge than the composition of the phases at an invariant point) the fixing of the order of succession of the $(n+2)$ P - T curves which proceed from an invariant point in a system of n components and (when the state of aggregation of the phases is known in addition) the fixing of their actual position within fairly narrow limits. This is illustrated by considering the P - T curves which proceed from the five quintuple points in the ternary system H_2O - K_2SiO_3 - SiO_2 .

The general relation given above between the variations in pressure and temperature (equation 129 of Gibbs) is not in a form which is convenient to apply. A general method is given for casting it into a convenient form for practical use and a concrete interpretation of the coefficients involved is given. In a system of three components, the equation becomes:

$$\frac{dP}{dT} = \frac{(\eta_3 - \eta_4) + \frac{A_{234}}{A_{123}}(\eta_1 - \eta_3) - \frac{A_{134}}{A_{123}}(\eta_2 - \eta_3)}{(v_3 - v_4) + \frac{A_{234}}{A_{123}}(v_1 - v_3) - \frac{A_{134}}{A_{123}}(v_2 - v_3)}$$

In this the subscripts 1, 2, 3, 4 refer to the different coexisting phases; the coefficients A_{123} , A_{134} , A_{234} refer to the areas of the triangles formed by connecting up the points in the composition diagram representing the composition of phases 1, 2, and 3; 1, 3, and 4; and 2, 3, and 4, respectively, the areas being circumscribed in the directions given. The application of this equation to the actual slope of the P - T curves, and especially to the change in slope with change in composition of phases of variable composition, is discussed in detail, taking as examples typical P - T curves from the ternary system H_2O - K_2SiO_3 - SiO_2 .

- (5) The necessary physical assumptions underlying a proof of the Planck radiation law. F. Russell v. Bichowsky. Phys. Rev., 11, 58-65 (1918).

In order to prove Planck's radiation law by means of the quantum theory only two physical assumptions need be made: first, that energy is absorbed or

radiated by a radiating system in quanta of $h\nu$; second, that a radiating system has the statistical properties of a perfect gas, *i. e.*, that Maxwell's distribution law holds for the distribution of the local values of the energy among the coordinates defining the state of the radiating system. (The usual auxiliary assumptions, such as Planck's oscillators or Larmor's regions of equal probability, are not only unnecessary but misleading.)

Although these two assumptions are sufficient for deriving the Planck radiation law, both of them, and particularly the latter, are very dubious, it being almost unthinkable that a radiating system can have the statistical properties of a perfect gas and yet not have the equipartition law hold. For these and other reasons it seems necessary to give up at least the second of the quantum hypotheses and to assume that the distribution of energy in a radiating system does not obey Maxwell's law—that is, to assume that in a radiating system the distribution of the local values of the coordinates is a function not only of the energy of the system but also of some other variables. If we do this and assume, for definiteness, that the distribution of the local values of the generalized momenta is a function not only of the total energy E of the system but also of the Helmholtz free energy A , and further assume that the total energy of a radiating system can not be less than a certain limiting value E_0 (E_0 turns out to equal $h\nu$), we can, following the methods of Gibbs and Ratnowsky, derive in a very simple manner the Planck radiation law, and moreover we can do this without assuming discreteness of radiant energy, without contradicting classical mechanics (equipartition does not hold for systems of this kind), without discarding infinitesimal analysis or without contradicting thermo-dynamics or the direct experimental evidence of the photoelectric effect that the $h\nu$ law holds only as a limiting case.

A translation of the mathematical part of "The entropy equation of solid bodies and gases and the universal quantum of activity," by Simon Ratnowsky (Ber. phys. Ges., 16, 232, 1916) is appended.

(6) The color of inorganic compounds. F. Russell v. Bichowsky. J. Am. Chem. Soc., 40, 500-508 (1918).

It is shown that every valence state of an element can be associated by means of purely experimental evidence with a definite "atom color." There is a marked relation between atom color thus determined and valence and valence variability. The atom color of every element in its normal valence state, that is, in the valence state which corresponds to its place in the periodic system, is zero (all non-variant-valence atoms have their normal valence). The atom color of an element, in valence states where the valence is decreased or increased by an odd number from the normal valence, lies further in the blue than the atom color of the same element in any other valence state. The atom color of an element in a state whose valence is removed by an even number from normal will be zero if compounds of the element do not exist in which the valence of the element is removed by an odd number from normal; otherwise the atom color will lie further in the yellow than the atom color of the same element in a state of valence removed by an odd number from normal. Compounds between non-variant-valence elements will be colorless. Compounds between a non-variant-valence element and a variant-valence element will have the same color as the "atom" of variant-valence element. Compounds between other elements will have colors more to the blue than the sum of their atom colors. All these regularities can be deduced from a variation of Lewis's theory of atom structure. The almost perfect accord between the deduction and the facts indicates very strongly that Lewis's

fundamental hypotheses are correct. Manganese, *eka*- and *diva*-manganese probably belong in the eighth group with iron and the rare earths, and not in the seventh group with chlorine. Mercurous, gallous, and indous salts are probably double complexes. So is the ferric ion.

- (7) Italian leucitic lavas as a source of potash. Henry S. Washington. *Met. and Chem. Eng.*, 18, 65-71 (1918).

This paper attempts an evaluation of the total amount of potash that is present in the lavas of the six chief Italian volcanoes along the west coast that have erupted leucitic lavas, which are therefore high in potash. The total volume of the solid mass of each volcano was calculated, a base being assumed and corrections made for craters and other features. An estimate was also made of the ratio of the lava-flows to the total bulk of volcanic products, largely tuffs; and the percentage of potash at each was averaged from numerous analyses made, for the most part, by the author.

From the data it is concluded that the total tonnage of potash (K_2O) in the lavas is about 10,000,000,000 tons; and this is regarded as a low estimate, because the tuffs and ashes, which form at least 90 per cent of the volumes, and which contain high percentages of potash, have not been taken into account. It is considered that in these volcanoes Italy possesses one of the largest if not the largest of the visible supplies of potash known to exist. Some other silicate-rock sources of potash are briefly discussed, especially the Leucite Hills in Wyoming and the belt of glauconite that extends from New Jersey into Virginia. The latter is shown to contain about 2,034,000,000 metric tons of potash and to be a valuable source of supply.

- (8) Thermal leakage and calorimeter design. Walter P. White. *J. Am. Chem. Soc.*, 40, 379-393 (1918).

The interchange of heat between a calorimeter and its environment (thermal leakage) is practically proportional to their temperature difference, except for the effect of evaporation and for that of convection, which is, for ordinary calorimetric conditions, more nearly proportional to the square of that difference.

If evaporation is suppressed the advantages of a constant thermal leakage factor are obtained by preventing convection. Recent investigations upon convection show how this may most advantageously be done. Diminishing the width of the air-gap around the calorimeter diminishes convection very rapidly, and this can be carried far enough to be effectual without too great an increase of the total thermal leakage, which is then mainly due to *conduction*, and therefore increases about in inverse proportion to the gap width. Gaps of from 1 cm. to 1.7 cm., according to circumstances, are best with ordinary calorimeters.

With large calorimeters, where the temperature change is less, freedom from detrimental convection is compatible with gap widths greater than those most desirable for small calorimeters. This possibility increases the relative value of the large calorimeter.

In adiabatic work there is little fear of convection, hence either very large temperature intervals or very large air-gaps can be profitably employed.

Very thin reflecting shields around the calorimeter may be used so as to diminish conduction, and thus decrease the total thermal leakage without increasing convection.

Incidentally, it is pointed out that the ordinary rule, that thermometric lag causes no error where only one thermometer is used, deserves careful interpretation, or else restatement, in the case of some thermochemical determinations.

- (9) The significance of glass-making processes to the petrologist. N. L. Bowen. *J. Wash. Acad. Sci.*, 8, 88-93 (1918).

Contrary to certain claims that have been made, glass-making processes offer no support to the belief in liquid immiscibility among silicates nor to the belief in a significant density stratification in a mass wholly liquid. They do, however, suggest the importance of gravity acting on a mass partly solid and partly liquid and emphasize two stages: (1) that at which there is much liquid and little solid, and (2) that at which there is little liquid and much solid. In magmas these two stages are probably those during which the most significant results in the way of differentiation are accomplished.

- (10) The ternary system $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$. G. A. Rankin and H. E. Merwin. *Am. J. Sci.*, 45, 301-325 (1918).

The temperature-concentration relations of the various crystalline phases in equilibrium with liquid in the ternary system $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$ have been investigated, and are represented by diagrams and a model. A ternary compound, $2\text{MgO}\cdot 2\text{Al}_2\text{O}_3\cdot 5\text{SiO}_2$, unstable at its melting-point and considerably affected by solid solution, has been observed in two forms. The μ -form (unstable) crystallizes from glass at temperatures below about 950° , and transforms at somewhat higher temperatures into the α -form (stable). The properties of both forms, but especially the α -form, are close to those of the mineral cordierite. The effects of solid solution in flattening two of the boundary curves of the field of this compound are discussed. The preparation and properties of crystalline aggregates of substances which dissociate when melting are considered.

Crystals of natural cordierite dissociate when melting. Brief consideration is given to the effects of FeO in magnesian rocks and minerals.

- (11) Chemical analyses of igneous rocks, published from 1884 to 1913, inclusive, with a critical discussion of the character and use of analyses. Henry S. Washington. Prof. Paper 99, U. S. Geol. Survey (1917).

Reviewed under No. 29 of the annual report for 1916 (Year Book No. 15, p. 156).

- (12) Crystals of barium disilicate in optical glass. N. L. Bowen. *J. Wash. Acad. Sci.*, 8, 265-268 (1918).

In some types of barium crown glass, crystals which ruin the glass for optical purposes may be formed at certain stages of its manufacture. While attempting to discover a means of eliminating the formation of these crystals it was found desirable to determine their nature. They proved to be the compound BaSi_2O_5 , hitherto unknown. Crystals of BaSi_2O_5 have the following properties: orthorhombic crystallization in six-sided plates with negative elongation. $2V=70^\circ$, $\gamma=1.617$, and $\alpha=1.598$.

- (13) Augite from Stromboli. S. Kozu and H. S. Washington. *Am. J. Sci.*, 45, 463-469 (1918).

This paper records the optical characters and chemical composition of the augite crystals that were being thrown out of the volcano of Stromboli during the visit of A. L. Day and the authors in August 1914. Analyses of the lavas are also given. The augite is shown to be of a commonly occurring type. The paper is part of an investigation on the augites and other pyroxenes of Italian and other localities.

- (14) An improved form of thermo-regulator. John B. Ferguson. J. Am. Chem. Soc., 40, 929 (1918).

This regulator differs from the usual type in that the coarse and fine adjustments are made by means of a plunger and plunger-tube which regulate the height of the mercury in respect to a fixed platinum wire.

- (15) The work of the Geophysical Laboratory. Robert B. Sosman. Am. J. Sci., 46, 255-258 (1918).

A brief statement of the plan and an outline of the results of the Laboratory's work on mineral systems, prepared for the chapter on mineralogy in the anniversary number of the American Journal of Science.

- (16) The place of manganese in the periodic system. F. Russell v. Bichowsky. J. Am. Chem. Soc., 40, 1040-1046 (1918).

The older arguments placing manganese in the seventh group of the periodic system (*i. e.*, giving manganese a normal valence of 7) now appear open to question. On the other hand, there are 12 different lines of argument based on purely chemical relationships which indicate its position in the eighth group. This conclusion is also in accord with the more decisive reasoning based on atom color presented in a previous paper. (See "The color of inorganic compounds," reviewed under No. 6.)

An improved form of the periodic table, showing the relations of the eighth and rare-earth groups to the rest of the periodic system, is presented.

- (17) Temperature uniformity in an electric furnace. John B. Ferguson. Phys. Rev., 12, 81-94 (1918).

The problem of temperature uniformity in an electric furnace is intimately connected with almost all investigations carried on at high temperatures. For this reason it has generally been considered as a part of a larger problem and has been solved to the extent demanded by the requirements of the work at hand. In this paper the writer presents a more general discussion of the subject, together with many results obtained by him in his various investigations bearing directly thereon.

The production of temperature uniformity in an electrically heated air-column may best be done by means of three independent heaters and end-plugs. The entire region to be heated should be surrounded by a layer of conducting material sufficient to smooth out any local heatings and the whole furnace so insulated that the effect of non-uniformity in the temperature of the furnace surroundings is rendered negligible. The use of alternate layers of good and poor conductors will reduce the total amount of insulation necessary, but if constancy of temperature as well as uniformity is desired, the insulation must be of such thickness as to eliminate the effect of temperature fluctuations in the furnace surroundings during the period the furnace is in use. This type of furnace has the advantage that it may be converted into a simpler type if less uniformity is adequate by merely changing the mode of connecting the heaters.

A furnace embodying these principles is described in detail. This furnace yielded a temperature uniformity of $\pm 0.5^\circ$ C. at temperatures ranging from 620° to 1190° , and at 1000° and 1190° C. a temperature constancy of $\pm 0.25^\circ$ for periods of time exceeding an hour. With greater care in adjustment a uniformity of $\pm 0.2^\circ$ C. should be possible, and without doubt the furnace could be run at much higher temperatures without great loss in efficiency. The furnace is economical of current and will reproduce practically the same conditions on different days with the same amount of current, provided the temperatures are below that at which magnesia powder begins to pack.

Some results indicative of the behavior of several different furnaces and set-ups are presented for their comparative value and also with the view of indicating the magnitude of some of the effects obtained.

- (18) The melting-points of cristobalite and tridymite. J. B. Ferguson and H. E. Merwin. *Am. J. Sci.*, 46, 417-426 (1918).

The melting-point of cristobalite has been redetermined and found to be $1710 \pm 10^\circ \text{C}$. This value is consistent with the experimental evidence which was obtained in a study of a portion of the ternary system $\text{CaO}-\text{MgO}-\text{SiO}_2$ and which had caused the earlier investigations to be viewed with suspicion.

Tridymite is unstable at its melting-point, and this unstable melting occurs at $1670 \pm 10^\circ$. Artificial tridymite made from quartz could not be melted, owing to the rapidity of the tridymite-cristobalite inversion, but a sharp melting was obtained with natural material. Since this unstable melting-point is below that of cristobalite, there can no longer be room to doubt that cristobalite is the high-temperature form of silica.

The determinations were carried out in a furnace specially designed for the purpose, which can be heated to and maintained at temperatures slightly above 1700°C . The furnace is constructed on the cascade principle: the inner coil is of an alloy of platinum with 20 per cent rhodium, the outer coil of pure platinum. The two coils are insulated from each other by well-burned magnesia powder, and the inner coil is wound on a helically grooved magnesia tube.

- (19) The equilibrium between carbon monoxide, carbon dioxide, sulfur dioxide, and free sulfur. John B. Ferguson. *J. Am. Chem. Soc.*, 40, 1626-1644 (1918).

This paper contains an extended account of the investigation of the reaction $\text{CO} + \frac{1}{2}\text{SO}_2 \rightleftharpoons \text{CO}_2 + \frac{1}{4}\text{S}_2$, a partial summary of which appeared last year. (See "The equilibrium between carbon monoxide, carbon dioxide, sulfur dioxide, and free sulfur," reviewed on p. 147, Year Book No. 16.) The study was undertaken primarily as a part of a comprehensive study of certain gas reactions and their rôle in volcanic activity, and this particular reaction was selected because it afforded a direct means of determining the free energy or thermodynamical potential of sulphur dioxide, one of the most important of the volcanic gases.

Two methods of attack were employed in the research: the stream method and a semi-stream method. The former was found to be inadequate chiefly because of subsidiary reactions which occur at low temperatures, and the latter was devised to overcome this source of trouble. In this latter method, a volume of gas is maintained at a constant uniform temperature for sufficient time to enable the mixture to attain an equilibrium condition, and then a *part* of the gas is quickly withdrawn into a cold evacuated vessel. The sampling takes from 0.1 to 0.2 of a second, and yields samples ranging from 15 to 25 c.c. in volume for analysis. Equilibrium can be reached at 1000°C . with the aid of a contact mass of platinized crushed porcelain, and barely reached without such a catalyst at 1180°C . In all equilibrium mixtures obtained at or above 1000°C . the presence of COS could not be detected. This fact not only greatly facilitated the analytical work in the later stages of the research, but established beyond a doubt the efficacy of the sampling method, since the velocity of the reactions producing the COS greatly exceeded the velocity of the reactions under investigation.

The composition of the equilibrium gas-mixtures obtained, with the corresponding initial gas-mixtures, both calculated and actual, and the resulting equilibrium constants, are given in tabular form, and the thermodynamical calculations based thereon given in detail. The latter give an average mean value of 3.99 for the thermodynamical constant I and -22510 calories for

the change in free energy for the reaction under standard conditions. For the reaction $S_R + O_2 \rightleftharpoons SO_2$ under similar conditions, the value for the change of free energy is -69761 .

These quantities will subsequently be made use of in calculating various equilibria in which sulphur dioxide plays a part.

- (20) The representation of a volcano on an Italian renaissance medal. H. S. Washington. *Art and Archæology*, 7, 256-263 (1918).

This paper describes a lead medal of Leonello Pio, Count of Carpi, which dates from the beginning of the sixteenth century. The reverse represents a volcano in violent eruption, and it is shown that this commemorates almost certainly an eruption of Vesuvius in 1500, concerning the actuality of which there has existed considerable doubt. If so, this is the earliest known representation of Vesuvius in eruption.

- (21) Some points regarding calorimeter efficiency. Walter P. White. *J. Franklin Institute*, 186, 279-287 (1918).

This discussion has special reference to the precision required and the conditions prevalent in commercial work.

The errors directly affecting a calorimeter may be reduced to two sorts: (1) the most important, usually, are those in the principal thermometer readings; (2) the most varied are those in determining the effect of leakage of heat from the calorimeter during the experiment. The principal sources of these errors are: (a) imperfect control of the surrounding temperature; (b) insufficient stirring in the calorimeter; (c) irregular heat production from irregular speed of stirring; (d) evaporation; (e) lagging temperatures. The last are usually negligible in commercial work, and the other errors can be made so. In the very similar determinations of commercial work these small errors tend to cancel out between calibration and final measurement, and thereby certain short methods become possible. In the main, these make for convenience, while precision depends mostly on the thermometer and more on control and definiteness of such things as jacket temperature than on special methods. The adiabatic method does not improve the situation regarding errors *a*, *b*, and *c*; and error *d* can be otherwise managed. This method is probably less valuable in commercial work than elsewhere. A mere glass-jacketed vessel is not rightly called adiabatic; it has a leakage-rate as much as one-third or one-fourth that of an ordinary calorimeter.

- (22) Note on a universal switch for delicate potential measurements. Walter P. White. *Am. J. Sci.*, 46, 610-612 (1918).

This paper describes two improvements found to be desirable after trial of the switch described in 1916 ("A universal switch for thermo-element work and other potential measurements," reviewed on page 146, Year Book No. 15).

- (23) The specific heat of platinum at high temperatures. Walter P. White. *Phys. Rev.*, 12, 436-441 (1918).

The specific heat of platinum has been redetermined from 100° to 1300° with a precision estimated to be better than 0.3 per mille and with very satisfactory agreement with the results of Gaede at 100° and with those of Plato, Corbino, Magnus, and Fabaro at higher temperatures. Most published results below 100° appear to be 1 per cent or more too high. The atomic heat of platinum at constant volume is, from 100° up, above the value 5.96, indicated by Dulong and Petit's law and by the accepted kinetic theories of the solid state, and also increases regularly to 1300° and probably beyond that.

- (24) Description of the quantitative classification of igneous rocks. Henry S. Washington. Extract from Professional Paper 99, U. S. Geological Survey (1918).

This is a reprint of the appendices to Professional Paper 99 (pp. 1151-1185) (reviewed under Abstract No. 11 of this report), embodying a description of

the quantitative system of classification, a tabulation of its divisions and names, a description of the method of calculating the norm, and tables giving the molecular numbers of the chemical constituents, and the percentage amounts of the mineral molecules, of igneous rocks. A list of the corrigenda to Professional Paper 99 is also included.

- (25) Manual of the chemical analysis of rocks. Henry S. Washington. (Third edition, John Wiley & Sons, New York, 1918.)

This is a much enlarged and entirely revised edition of a book originally published in 1910. Particular attention has been paid to the discussion of the sources of error, both operative and methodic, and the various operations and methods are described in greater detail than formerly. The revision embodies the results of six years' experience gained in the Laboratory.

- (26) The calculation of the rational analysis of clays. Henry S. Washington. J. Am. Ceram. Soc., 1, 405-421 (1918).

This paper discusses briefly the factors that render the so-called "rational" analysis of clays uncertain, erroneous, and of little or no value for any purpose. A method for calculating from the chemical analysis the mineral composition, generally quartz, feldspar, and kaolin, is suggested, which is an application of the principles and methods of calculating the "norm" of igneous rocks. In the case of clays the procedure is of great simplicity and accuracy, is very expeditious after the chemical analysis has been made, and yields results of great reliability.

- (27) The conditions of calorimetric precision. Walter P. White. J. Am. Chem. Soc., 40, 1872-1886 (1918).

In a calibrated calorimeter practically all the errors come in temperature measurement, and the most, though often not the greatest, of these come in the "cooling correction," that is, the determination of the effect of the thermal leakage between calorimeter and environment.

This leakage effect is equal to $K\phi_x T$, where T is time, ϕ_x is the thermal head (difference of calorimeter and environment temperature) for the experimental period, and K the thermal leakiness, or leakage modulus, of the calorimeter. If any of these three quantities is diminished its own errors are usually little changed, but the errors of the others now have a smaller multiplier. Thus:

1. By diminishing K (as by means of a vacuum) we diminish the effect of errors in ϕ_x , which lie (a) in getting the environing (jacket) temperature sufficiently uniform, (b) in getting the calorimeter temperature uniform without too great an error from heat of stirring. This latter difficulty grows in importance as measurements become more delicate. Usually, errors in ϕ may easily be made negligible, and great diminution of K is then of secondary importance.

2. A diminution in ϕ , as by the adiabatic method, or by methods similar to that of Rumford, diminishes the effect of errors in K , such as variation from Newton's Law. But owing to the peculiarities of the computation, it does not much affect the main error connected with K , that in determining K by means of the cooling rate, unless methods can be used which presuppose an accurate knowledge of the heat of stirring. For this and other reasons, the diminution of ϕ , though the commonest of operative devices, is in practice largely illusory as far as concerns the end chiefly sought. The determination of K generally results in about doubling the accidental thermometric error, but this is usually the largest thermal leakage error there is in well-planned work. This error can be diminished by devices some of which are adapted to commercial work and which save time as well as error.

3. Lags have a law of their own; they usually vary with K , are independent of T and ϕ , and can usually be made to cause little or no error.

4. The stirring introduces a possible error from irregular heat production, due to irregular speed. Since the heat varies as the curve of the speed, the error tends to vary as the cube of the efficiency of stirring, and thus may become very important in delicate measurements. A remedy can usually be found by controlling the speed, or, more effectively, by diminishing K_1 as already noted. The type of stirrer, and the design of the calorimeter with reference to stirring, may be very important. Evaporation is also touched upon, and a discussion is given of the error from heat-flow along wires or rods.

(28) Calorimetric methods and devices. Walter P. White. *J. Am. Chem. Soc.*, 40, 1887-1898 (1918).

In this paper various forms of jacket covers (and of stirrer mountings) are described and compared.

Vacuum-jacketed vessels are mainly useful either in relatively crude or in very exacting work. They are convenient and simple in crude work, but cause difficulty and complication if the work to be done demands more elaborate arrangements. The adiabatic method does not diminish either of the two main sources of thermal leakage error, but has advantages in a dozen other ways. The Pfaundler twin-calorimeter method still enables high precision to be attained with relatively simple apparatus, but is most successful when applied to liquids and to the comparing of two things which are nearly alike. Aneroid calorimeters work quicker, and within limits also more accurately, the smaller they are. The measured shield method, where a convection shield supplied with thermocouples is used, diminishes very greatly the difficulties of thermal head measurement and stirring, which are among the greatest in work of high precision, and is more convenient than the use of glass vessels.

(29) Calorimetric lag. Walter P. White. *J. Am. Chem. Soc.*, 40, 1858-1872 (1918).

The lag effects of bodies external to calorimeters, although more complicated in expression, are found to follow the same general laws as the simpler lag effects already described. More carefully stated than previously, these effects prove to be three: (1) equivalent to the heat capacity of the calorimeter; this can be eliminated if a calorimeter is directly calibrated; (2) much smaller, depending on the amount of thermal leakage; this can be avoided, if necessary, by using the adiabatic method; (3) dependent on the jacket temperature, which disappears for constant jacket temperature; this one causes the calorimeter to have a different effective heat capacity when used adiabatically.

Of two errors that are peculiar to the aneroid calorimeter, one comes from improper distribution of the thermo-junctions (or equivalent devices) which measure the surface temperatures. This error becomes zero if the surface temperature distribution does not change from one experiment to another. The other special error is inconstancy of final temperature due to inconstancy of final temperature of the jacket.

On account of the lag effect the effective heat capacity of a shield midway between calorimeter and jacket is only one-fourth the actual capacity, and with due regard to the possibility of change, such shields may often with great profit be used to reduce the thermal leakage. Used as a cover, such a shield has a specially small error, and offers a particularly easy method of dealing with evaporation. Ordinary non-metallic covers, on account both of their lag and their heat capacity, are very undesirable.

Although a normal lag effect characterizes even thick and heterogeneous packings around a calorimeter, the loss of time due to the lag is a sufficient objection to the practical use of anything which is not either very small or in very close thermal connection with calorimeter or jacket.

- (30) The general character of specific heats at high temperatures. Walter P. White. *Proc. Nat. Acad. Sci.*, 4, 343-346 (1918).

The specific heats of three forms of silica and two silicates (alkali feldspars), determined for temperatures up to 1300° , indicate that the atomic heats at constant volume for the substances increase above the theoretical value 5.96, as the heats of metals have been known to do, and hence that such increase is a very general phenomenon, as has been suspected.

- (31) Solubility and fusion relations at high temperatures and pressures. George W. Morey. *J. Engineers' Club of Philadelphia*, 35, 509-519 (1918).

An address giving a popular discussion of the principles underlying the solubility relations of binary systems composed of both volatile and non-volatile components. In addition, some new compounds of the alkalis with Al_2O_3 and Fe_2O_3 are described, as well as a new method for determining solubilities under difficult experimental conditions.

- (32) Note on the sintering of magnesia. John B. Ferguson. *J. Amer. Ceram. Soc.*, 1, 439-440 (1918).

The sintering of chemically pure magnesia has been generally regarded as difficult if not impossible, and this note is intended to place upon record the conditions under which such a sintering was found to take place readily. Pure magnesia powder, upon prolonged heating at temperatures ranging from 1600° to 1720° C., sinters to a cake of considerable mechanical strength and this sintering is due to a recrystallization, forming a mass of interwoven crystals, rather than to the presence of any bonding materials.

- (33) The effect of certain impurities in causing milkiness in optical glass. C. N. Fenner and J. B. Ferguson. *J. Am. Ceram. Soc.*, 1, 468-477 (1918).

In the manufacture of optical glass at the Bausch & Lomb plant, a matter which gave considerable difficulty for a while was the occasional production of pots of glass which were affected by opalescence or milkiness. The evidence indicated that the source of the trouble lay in the sulphate and chloride content of the Russian potash to which recourse was had when the German supply was cut off, although certain facts tended to cast doubt upon this conclusion. It was found, however, that the trouble disappeared when more reliable methods of temperature-control were installed, by which an assurance could be had of keeping the temperatures constantly at 1400° to 1420° C., and when the Russian potash was replaced by an American product more nearly free of impurities. Later, evidence was obtained which connected the milkiness quite definitely with the impurities mentioned, at least as regards the case under discussion, although in other cases the same effect is to be ascribed to other causes.

Reasons are given for the conclusion that the milkiness is caused not by the separation of sulphates or chlorides themselves, but to some slight change in the physical properties of the melt which permits the separation of clouds of minute crystals of cristobalite.

A discussion of this paper by Mr. F. Gelstharp, of the Pittsburgh Plate Glass Company, and the authors is contained in the next succeeding number of the *Journal of the American Ceramic Society*.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. FRANKLIN JAMESON, DIRECTOR.

The following report, the thirteenth annual report rendered by the present Director, covers the period from November 1, 1917, to October 31, 1918. A year of war is necessarily abnormal. For such a department to attempt to continue its usual activities unchanged, enveloping itself in "the still air of delightful studies" and ignoring the tragic struggles of the world without, would be both pedantic and disloyal, and would show a pitiful inability to appreciate the higher duties which such an institution owes to its country. From the entrance of the United States into the war, the Department has wished always to perform any services it could render to Government or Nation. But it was clear from the outset, to anyone knowing the composition and character of the historical profession in the United States, that such services could be far better performed through an organization resting on a broad basis of general cooperation than through any plans or efforts made by our Department attempting to work alone. Therefore the Department welcomed and assisted the formation of the National Board for Historical Service in May 1917, and has been entirely content that all its labors since then, in the way of attempting to help the Government or the public in war time, should be mingled indistinguishably with those of the Board. That organization has engaged in a wide variety of useful war services. The time has not yet come, nor is this the place, for describing these services with fullness, but allusion is made to the activities of the Board in order that readers of this report, to whom the Department's record of achievement for the past year may seem a slight one, may bear in mind that much of its labor has been expended through channels not here described. Two members of the staff, for instance, have been almost wholly engrossed throughout the year in the work of the Board, Mr. Leland as its secretary, Mr. Stock as assistant secretary, and have had almost no time to apply to their customary lines of work. The Director has since December been a member of the executive committee of the Board; Dr. Paullin has given it much help in matters of historical geography; and other members of the staff have spent in its service considerable portions of their time.

Miss Catharine Bowes, who for twelve years had served the Department as a singularly accurate copyist, resigned in June to enter the overseas service of the American Red Cross. Mr. Irvin H. Campbell, who for nearly four years had given most acceptable service as stenographer, also resigned in June. Miss Donnan had leave of absence for the second semester of the academic year 1917-1918, to act

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as substitute for the professor of political economy in Mount Holyoke College, and has similar leave for the first semester of the present academic year, but was with us during winter and summer. On the former occasion her place was taken by Miss Elizabeth G. Greene, on the latter by Miss Esther E. Galbraith.

From the beginning of February to the end of August, the Department, to its great pleasure and profit, had the constant presence and assistance of Professor Evarts B. Greene, of the University of Illinois, as Research Associate of the Institution and chairman of the National Board for Historical Service. It is difficult to speak in moderate terms of the service his work and character rendered to the Board and the Department. His leave of absence from the University of Illinois expiring in September, a reorganization of the Board was then effected, Professor Dana C. Munro, of Princeton University, becoming its chairman, Professor Joseph Schafer, of the University of Oregon, vice-chairman. Dr. Victor S. Clark, formerly of the Department of Economics and Sociology of the Carnegie Institution of Washington, and a member of the Board, has since March been constantly occupied with a special division of the Board's work, and thus associated with this Department.

As in previous years, acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, the Librarian, by Dr. Gaillard Hunt, chief of the Division of Manuscripts, and by Mr. P. Lee Phillips, chief of the Map Division. Grateful recognition is also made of special courtesies extended by the authorities of the library of Harvard University, especially during the summer months, to several members of the staff.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

Previous reports have shown the gradual preparation and issue of a series of guides to the materials for American history preserved in the various national archives of Europe, a series which was approaching completion when the war broke out. Little progress toward the completion of the series can be achieved during the continuance of warfare. The volumes for the Netherlands, the Scandinavian countries, Scotland and Ireland, and the British West Indies can not be begun until the war is ended. As to the "Guide to Materials for American History in the Archives of Paris," although Mr. Leland's duties as secretary of the National Board for Historical Service have prevented him from devoting much time to the volume which he intended to elaborate first, that on American manuscripts in the libraries of Paris, it has been possible for clerical assistants working

in Paris, under his direction, to make considerable progress toward the final completion of his collection of data.

At the beginning of October 1917, Mrs. N. M. Miller Surrey had begun a large undertaking allied to the completing of this Paris guide. During the years which Mr. Leland had spent in accumulating notes for the latter work, and by a partly similar process, data had been gathered, at the cost of a group of Western historical societies and similar institutions, for the making of a calendar of all the papers in Paris archives and libraries bearing on the history of the Mississippi Valley. This Department having assumed the remaining stages of the preparation of this calendar, the stages subsequent to the first process of taking notes, Mrs. Surrey has been engaged to edit the notes, bring them into a uniform text, compare duplicates, distinguish originals from transcripts when possible, and otherwise make the work ready for publication. Meantime, however, the Library of Congress has in recent years acquired for its Division of Manuscripts a large mass of copies from the Paris archives embracing many of the documents which would be listed in the proposed calendar. It was therefore expedient that the process of preparing a uniform text from the notes taken by the searchers in Paris should include verification of their condensed summaries of the documents, by means of the transcripts of them in the Library of Congress, whenever such transcripts had been acquired. Experience has shown that this process of verification, amounting in many cases to the making of new summaries, is profitable and will tend to the reader's ultimate advantage, but it consumes time. Mrs. Surrey has now nearly completed that portion of her calendar in which such comparison with the transcripts in Washington is possible. The remainder of the calendar, though a larger part of the ultimate product than what has now been finished, will proceed much more rapidly.

Work on the "Atlas of the Historical Geography of the United States" has of necessity proceeded slowly during the past year. Persons of the class that would normally be called upon for assistance to Dr. Paullin have been in a peculiar degree liable to calls from the Government in war time. Dr. Paullin himself, with the draftsman's aid, has during the year completed two allied series of maps and has written the accompanying letterpress. One of these series exhibits, on the basis of such data as can still be obtained, the growth of towns in the colonial and Revolutionary periods; the other shows from census to census, from 1790, the growth of urban population, at the same time exhibiting the changing outlines, from decade to decade, of States and Territories. Concurrently, a considerable amount of progress has been made with the series of maps showing, at different periods, the negro and slave population of the United States. Dr. Paullin has also supplemented a series previously completed, by pre-

paring a map showing the results of the presidential election of 1916, in the same manner as that employed in the case of previous electoral contests.

In the concluding weeks of the period reported upon, a beginning has been made in the case of another aid to research which it is hoped may prove serviceable to many investigators in American history. The manuscript materials in Europe for that history are to be found in repositories of two sorts—archives and the manuscript departments of libraries. Into the former, papers bearing on American history have come for the most part in continuous series, in the ordinary course of public business relating to America, colonial or independent; into the latter they have most commonly come singly or casually. It is therefore a much more difficult, time-consuming, and expensive process to list exhaustively the manuscript materials for American history preserved in European libraries than to prepare, as has been done in our series of "Guides," a relatively adequate "first-aid" treatment of archive materials of similar bearing. It happens that, for reasons deemed sufficient to warrant the exception, we have done it in the case of the libraries of London, Oxford, Cambridge, Paris, and Rome. But to do it for all the libraries of Europe, and especially for the multitudes of small provincial or local libraries in which some very small number of manuscripts relating to America may lurk among hundreds or thousands of others, like the proverbial needle in the haystack, would call for such a prodigious effort, so great a consumption of time and money, that, if we may not say that the Institution could never afford it, at least we may confidently declare that it must stand relatively late among our undertakings, and that its completion could not be expected by the present generation of scholars.

Meanwhile, however, a "first-aid" procedure is possible, which would enable us to "serve the present age" by presenting before long a considerable share of the data which a complete search would disclose. Many of these libraries have in past times printed catalogues of their manuscript treasures, either as separate volumes or as appendices to their catalogues of printed books. The searcher of one of these catalogues will perhaps come upon a stray item describing some manuscript bearing on American history, but it is most likely something for which he personally has no use, "not in his period," and there are hundreds of such catalogues, and probably no student of American history has ever searched them all. A library in a French provincial capital contains one American manuscript, a long memoir by General Turreau of his mission to the United States, which almost certainly no student of Jefferson's diplomacy has ever seen. The library of one of the Swiss cantons contains an illustrated journal of travel in Virginia by one of the earliest foreign travelers in that colony, a manuscript which no American seems to have seen till a few years

ago, but so interesting and valuable that the Virginia Historical Society has now published a translation of it. The same catalogue shows one other American manuscript in the library, and but one; it relates to an entirely different field.

Now if a compilation could be made of all the American items in all catalogues of the sort, British, French, Spanish, German, Italian, and properly indexed, it would reveal to the student a large amount of material almost wholly unknown to him hitherto. In this conviction, arrangements were made with Mr. David M. Matteson, an accomplished student of American history, practised in library methods, who has begun drawing off from these catalogues their American items. It will be understood that no effort can be made to verify these data by examination of the manuscripts themselves, that the catalogue entries will for the present be taken at their face value and simply copied, and that the descriptions are widely disparate in form of presentation; but, taken as they are and combined in the manner indicated, they will be distinctly useful.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

Aside from "war work," Miss Davenport has been able to make ready for publication four more treaties, 1661-1665, for the second volume of her "European Treaties bearing on the History of the United States."

In Dr. Burnett's series of "Letters of Delegates to the Continental Congress," besides making completely ready for print the manuscripts of the first two volumes, extending respectively to July 4, 1776, and to the end of 1778, he has advanced the preparation of the third volume through the month of December 1779.

Mr. Stock has, for reasons already indicated, been able to make very little progress with his edition of the "Proceedings and Debates of Parliament respecting North America"; but in the last month of the year under report Miss Galbraith has begun the decipherment and transcription of the American portion of Henry Cavendish's notes of debates in the House of Commons of 1768-1774, from photographs of pages of the original shorthand among the Egerton Manuscripts in the British Museum.

Miss Donnan, in portions of her time not occupied with her work upon the *American Historical Review* nor embraced in her leaves of absence, has continued her search for and examination of material upon the American slave-trade, the sources and methods of supply. From sources printed, but as a rule not accessible in most libraries, and unprinted, she has accumulated material for a sizable volume of much interest and value to students; but the search, hitherto mostly conducted in Washington, Boston, and Cambridge, must be extended to manuscripts in several other American cities, and especially in the

British Museum and Public Record Office (from both of which, however, some materials have already been secured), before any such degree of completeness will have been achieved as will warrant publication.

Meanwhile, Professor John S. Bassett, of Smith College, was so good as to place at the disposal of the Department the greater part of his time during the summer and to advance the search for materials for Miss Donnan's book, especially in respect to the nineteenth century, by investigations in the Manuscripts Division of the Library of Congress and in the archives of the Navy Department. In the former the search extended through the papers of the African Colonization Society, the Slave-trade Papers formerly transferred from the Department of the Interior, etc.; in the latter, through the Squadron Letters and Captains' Letters from the African Station during the period after the passage of the act of 1807, which made the importation of slaves into the United States from Africa illegal. It is a pleasure to acknowledge not only Professor Bassett's aid, but the kindness of Mr. Charles W. Stewart, superintendent of the Office of Naval Records in the Navy Department, in facilitating his labors.

Work was begun in July on another portion of the Department's series of documentary volumes illustrating the social and economic history of negro slavery in America. A rich store of actual instances, showing in detail nearly every aspect of American slavery, is to be found in the judicial reports of the States in which slavery flourished. They are instances which no one selected to prove a case, pro or contra; they are simply such as naturally arose in the course of legal business. The narratives embedded in these reports are therefore excellent material for the historian; and the decisions rendered by the courts supplement and correct those views of the law respecting slavery which might be derived from the statutes, standing alone, to which another publication may be devoted. Since in planning the series the social history of slavery is regarded as a more important object than the history of the law respecting slavery, it is intended that the substance of the judicial decisions shall be set forth with the utmost compression consistent with clearness and exactness of legal statement, while ampler space is thus secured for presenting the narratives and documents, often of great interest, which constitute the evidences for social and economic history. For the difficult task of compilation along both these two lines, the Department has been so fortunate as to secure the services of Mrs. R. C. H. Catterall, a member of the Boston bar, and a lady possessing much exact legal and historical knowledge. She has completed her work for Maryland.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff. The

American Historical Association and various other historical organizations have been given such aid as could appropriately be rendered, in respect to investigations in Washington and other services, and many queries from individuals have been answered.

Especially interesting to the Department, although originating outside its normal sphere of operations, has been the matter of the Bandelier transcripts. In October 1911 the trustees of the Institution made a special grant to the late Dr. Adolph F. Bandelier, to enable him to pursue further, in the Archives of the Indies, at Seville, those documentary investigations into the history of the Pueblo Indians of the Southwest which in former times he had pursued so fruitfully in the archives of the City of Mexico and of the valley of the Rio Grande. Dr. Bandelier proceeded to Seville, but fell ill and died there before he had much more than begun his researches. Continuing them along lines indicated by him, Mrs. Bandelier made transcripts of a large mass of documents relating to the Pueblo Indians, which on her return to America were turned over to the Carnegie Institution of Washington, together with some transcripts previously obtained by her husband in Mexico. Dr. Bandelier's intention having been to supplement in Seville such documents as chance and skillful search had already brought into his way in America, this present collection bears naturally a somewhat accidental character, not marked by any high degree of unity; yet it contains much that is interesting, and taken as a whole is capable of forming an impressive collection, adding much to our knowledge of the early history of the Spanish-Indian Southwest, especially of the part along the Rio Grande.

That this gratifying result might be achieved, the Executive Committee of the Trustees requested this Department to take general charge of the work of preparing the transcripts for publication. Dr. Charles W. Hackett, then of the University of California, now acting assistant professor of history in that of Texas, a scholar having an intimate knowledge of Southwestern history, and apparently the best qualified person available, was engaged as editor. Under his direction, the work of copying the transcripts for the printer (a process made necessary by peculiarities of their form) has been completed, and his assistants have nearly finished the careful translations which are to accompany the texts. He has also done much of the work necessary for writing the introductions and annotations. It is probable that the year 1919 will see the task completed, within the appropriation made, and the book ready for print.

Some of the documents brought back by Mrs. Bandelier have been omitted, either because they were of insufficient importance or because their substance was already accessible in print. On the other hand, there were instances where a series of documents, incomplete as it stood, could be made more complete and more intelligible if gaps

should be supplied by the use of documents from one or another of three existing collections of transcripts of similar character preserved elsewhere in the United States. These are the collection also made by Dr. Bandelier, which resulted from the Hemenway Expedition of 1887, and which is now in the possession of the Peabody Museum of Archaeology at Cambridge; the great collection of Spanish transcripts accumulated by Mr. Edward E. Ayer of Chicago; and that preserved in the Bancroft Library at the University of California. To fill gaps of the kind indicated above, Dr. Hackett was asked to designate a limited number of documents from these collections which, with the permission of the owners, might be included in the volumes which he is preparing. With gratifying liberality, the desired permissions were readily accorded by Mr. Ayer and by the authorities of the Peabody Museum and the Bancroft Library, and arrangements have been made for the procuring of copies.

It is estimated that, texts and translations together, the collection will make three or four volumes of the ordinary size of the Institution's publications. Although they will be somewhat lacking in unity and completeness, as is natural from the method by which the original expedition was planned, nevertheless they will cast much new light on early Pueblo and other Southwestern history. One section, of much interest, consists of authentic reports concerning the services and merits of discoverers and conquistadores in New Spain, beginning with companions of Cortes. Another consists of documents relating to the administration of the Indies in the sixteenth and seventeenth centuries. The largest body relates to the conquest and subsequent internal affairs of New Mexico, extending over the whole period from 1593 to 1773. Other sections relate to the affairs of Nueva Galicia, Nueva Vizcaya, and adjacent regions. All Professor Hackett's proceedings thus far have been systematic and prompt, and, in view of his known scholarship in the field in question, a publication highly creditable to the Institution is to be expected.

PLANS FOR 1919.

War-time conditions make it in large degree futile to attempt to predict what progress the Department may be able to make in the next twelve months. It will certainly do all it can to aid the National Board for Historical Service in any ways the Board may desire; but in view of the constantly changing phases of the war, no one can say what aspects of the Board's work for Government or country will require the greatest emphasis, what sort of services the staff of the Department will from time to time feel called upon to render to it, or how much time will be left them to spend upon those regular tasks to which in happier times they would entirely devote themselves. The most the Department can promise is to make what progress is

possible under the circumstances. Like the rest of the historical world, it will strive to learn all it can, respecting the uses of history and the methods of its pursuit, from the grandiose and terrible events through which the world is passing, to reconsider its program in the light of this great conflagration, and to prepare itself to meet whatever needs historical labors of its class can supply for the new world that will emerge from the great conflict. In that new world, we shall be mindful, American scholarship will incur additional and pressing responsibilities because of the extent to which the war will have impaired or dried up all the sources from which in past times the enterprises of European scholarship have been maintained.

REPORTS, AIDS, AND GUIDES.

Mr. Leland will do what he can toward finishing that volume of his Guide to Materials in Paris which concerns manuscripts in libraries. Mrs. Surrey will doubtless finish her calendar of papers in Paris archives relating to the history of the Mississippi Valley. Listing some 25,000 documents, and indicating the contents of each, though with the utmost brevity, it will make a considerable work. Dr. Paullin will continue his work upon the Atlas of the Historical Geography of the United States; and the inventory of American material compiled from the printed catalogues of manuscripts in European libraries will probably be completed within the year.

TEXTS.

Miss Davenport will progress with her second volume of treaties; Dr. Burnett with the third and perhaps the fourth volume of his "Letters of Delegates to the Continental Congress"; Mr. Stock, if possible, with his Parliamentary materials; Miss Donnan with her materials for the history of the African slave-trade.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain, in 1919, activities similar to those which, under this heading, have been described above in that part of this report which relates to the year now closed.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYOR, DIRECTOR.

The yacht *Anton Dohrn* being in the service of the United States Navy, we were unable to conduct researches at Tortugas, Florida, and accordingly various expeditions were arranged for the prosecution of studies which had been begun at Tortugas but might profitably be extended into other regions.

Professor E. Newton Harvey returned from Japan in January 1918, whither he had gone under the auspices of the Department to procure material for the chemical and physiological study of substances which produce phosphorescence in marine animals. He succeeded in collecting a large quantity of material of *Cypridina*, a copepod remarkable for its luminosity. The results attained are recorded in his report published herewith.

Professor Ulric Dahlgren visited the Southern States to obtain material for the study of the histology and physiology of the light-producing organs of insects.

On March 8, 1918, the Director, accompanied by Professor A. L. Treadwell, Mr. Duncan Gay (artist), and the engineer of the Department, Mr. John Mills, started from New York for Pigeon Point, Tobago, British West Indies, returning on May 8; this was the Director's second visit to Tobago.

Arthur H. Cipriani, Esq., of Port-of-Spain, Trinidad, again kindly placed at our disposal the estate house in the coconut grove of Pigeon Point, Tobago, and his excellency Sir John Chancellor, governor of Trinidad, Hon. H. Pinckney C. Strange, commissioner-warden and chief magistrate of Tobago, and Harold Kernahan, esq., all gave us aid and counsel and assisted the expedition in many ways.

We took with us a small gasoline engine, which was installed in a hull purchased in Trinidad and sold, at the termination of our visit, to the police department of Port-of-Spain.

We equipped the house at Pigeon Point with necessary furniture and used it as a base for the study of the marine animals of the adjacent ocean.

Professor Treadwell has for some years been conducting a systematic study of the Eunicidæ of the coral reefs of the Atlantic Coast of North America. He had previously visited Tortugas, Bermuda, and Porto Rico, and it seemed desirable that he should pay special attention to the southernmost end, the West Indian chain of islands, in order to determine the range of these West Indian forms to the southward and the influence of South America upon the West Indian fauna *sensu*

*Situated at Tortugas, Florida.

stricto. He accordingly devoted his entire time to collecting and studying the Eunicidæ of Tobago, while Mr. Gay made colored drawings for the extensive work which Professor Treadwell is preparing upon this group of worms. Tobago being in the track of the northern branch of the Great Equatorial drift of the tropical Atlantic, afforded the Director an opportunity to continue his observations upon the siphonophores, and tows were made by Mr. Mills every morning at sunrise for this purpose, good results being achieved, despite the many years the Director has spent in seeking these animals in Atlantic waters.

We returned to New York on May 8, and it was our intention that Professors Treadwell and Gudger might visit Nassau, Bahamas, accompanied by Mr. Gay, but enemy submarines appearing off our coast, the sailing schedules of the steamers were so deranged that these plans were abandoned. However, the Director, accompanied by Professor L. R. Cary and Mr. John Mills, again visited Pago Pago, American Samoa, arriving there on July 1 and remaining until August 5, 1918.

Hon. Josephus Daniels, Secretary of the Navy, kindly permitted us to return to Samoa in order to continue the studies of growth-rate and other factors of coral reefs commenced by us before war was declared in 1917. We were provided with a Davis calyx drilling machine for drilling through the coral reef and bringing out a core, and the United States Shipping Board in San Francisco permitted us to transport this to Samoa.

To Commander John M. Poyer, U. S. N., governor of American Samoa, and to Lieutenant Commander L. W. Strum and other naval officers, it is a great pleasure to express our deep sense of gratitude for the kind reception given us in American Samoa. Not only were we the recipients of frequent and significant aid to our studies, but Governor Poyer placed the U. S. S. *Fortune* at our disposal to transport the expedition from Pago Pago to Apia, Samoa, thus expediting our return and making it possible for us to stop in Suva, Fiji, where we weighed, measured, photographed, and planted out 140 corals upon the barrier reef off the mouth of Suva Harbor, Viti Levu Island.

The results already attained show that madreporarian corals in Samoa grow about twice as rapidly as do similar genera off the Atlantic coast of Florida. For example, an *Acropora* which weighed 2 ounces in 1917 had grown to be 70 ounces at the time of our return 15 months afterwards. Moreover, due to their abundance and rapid growth-rate, the *Acropora* constitute the most important element in determining the outward growth of the Pacific coral reefs. The large *Porites* heads, dangerous to navigation, grow upward at an average rate of about an inch per year.

Barrels were set out over the edges of reefs swept by currents in order to determine the loss due to sand washed from the shallow reef

flats, and it was found that the amount of sand washed off from the reef flat of fringing reefs and destroyed by holothurians is greater than the weight of limestone gained due to the growth of corals upon the flat.

Professor Cary desired to drill through the fringing reef in Pago Pago Harbor in order to obtain a core so that he might determine the relative importance of the Alcyonaria in building up the reef, he having found that in Florida the Alcyonaria are more important as reef-builders than are the stony corals. Mr. Mills, using the Davis calyx drill, succeeded in drilling through the fringing reef off Utelei village, Pago Pago Harbor, 575 feet from shore, and ran into volcanic rocks underlying the coral reef at a depth of 121 feet. The material fragmented so readily, however, that no continuous core could be obtained, but it is believed that this difficulty can be overcome and upon our next return to Samoa another attempt will be made to solve the problem.

Moreover, we have found places so well protected from dangerous breakers that it will be possible to work in diving-hoods on the precipitous outer faces of the reefs and gain a quantitative knowledge of the conditions of coral growth on the submerged seaweed wall of the reef. The growth-rate of corals at various depths can also be determined, and possibly one may discover the reason for the decided reduction in the number of coral heads at depths greater than 20 fathoms. For this purpose also we hope to return to American Samoa as soon as war conditions will permit.

Many tests were made of the streams and springs of Tutuila and Upolu, Samoa, and of Viti Levu Island, Fiji, and all were either weakly alkaline, neutral, or so slightly acid that even the most acid would give a neutral solution upon being mixed with sea-water in the proportion of 8 parts of stream-water to 1 of sea-water.

It seems well established that the reef flats fringing these volcanic islands of the Pacific can not be dissolved by any hypothetical "acidity" of the usually alkaline surface water which drains outward into the sea. At the same time we must be mindful of the fact that the reason tropical sea-water does not dissolve coral reefs is that it is practically saturated with calcium. The stream-water of Tutuila is, however, only about 1/100 saturated with calcium, and thus when it dilutes the sea-water over the reef flats the mixture may dissolve calcium. Experiments are in progress to determine this effect.

The only acid streams found were the Tamavua, Lami, and Visari Rivers flowing into Suva Harbor, Viti Levu Island, Fiji, and these were only 6.6 PH or nearly neutral for the average temperature of 25° C. of these streams. It was found that in the dry season the springs and streams of Tutuila are less alkaline than they are in the wet season, when swollen by the seepage from the surface soil, containing as it does a considerable charge of sea salts derived from the ocean spray. On the other hand, the permanent springs which alone maintained the

streams during the phenomenal drought of 1918 were all slightly acid, due to carbon dioxide; but the water from the most acid of these springs became alkaline after falling over a cataract only 15 feet in height, and all of the Samoan streams appear to be alkaline in their lower ranges near the sea.

Daily determinations were made at noon of the hydrogen-ion concentration of the surface water of the ocean during the voyages from San Francisco to Samoa, Samoa to Fiji, and Fiji to Victoria, British Columbia; and, as in 1917, the results indicate that in the tropical region of the mid-Pacific a sudden change toward acidity usually indicates the presence of a surface current moving toward the east in opposition to the prevailing westerly surface-set. The rapidity with which this test can be made may be serviceable to navigation by indicating the presence of an easterly set even before the vessel has become deflected from its true course.

Tests of the surface waters were also made in the Atlantic on the voyage to and from Trinidad, British West Indies, and between New York and Key West, and these show that the Gulf Stream and tropical Atlantic waters are much more alkaline than the water which drifts down close to the east coast of North America from the Gulf of St. Lawrence to Cape Canaveral, Florida. The test of alkalinity is thus a valuable guide in this region to warn navigators who may be approaching the coast that they are on the inner side of the Gulf Stream, or in proceeding outward that they have reached the surface current of tropical origin.

The cold arctic water, or that from the depths of the ocean, is more heavily charged with carbon dioxide than is the warm surface drift of tropical origin, and even when the temperature of the waters derived from the depths, or from cold regions, has become practically the same as that of the surrounding water of tropical origin, its carbon-dioxide concentration still remains relatively high, thus causing it to maintain some of its relative acidity.

This suggests that easterly sets in the tropical regions of the mid-Pacific and Atlantic may be due to water of deep origin coming to the surface. Possibly there is a general easterly movement of the deep water of the tropics to counterbalance the prevailing westerly set of the surface; but the test of this hypothesis awaits confirmation.

The growth-rate of the Pacific corals being about twice as rapid as that of corresponding genera in the Atlantic, it becomes evident that the present reefs might readily have attained to their present dimensions during the past 30,000 years, or since the last Glacial Epoch. Possibly the fact that the Pacific corals grow more rapidly than do those of the Atlantic may be correlated with the condition that in the Atlantic the corals grow chiefly on the outer edges of wide, shallow flats covered with limestone mud, which when agitated fill the water of the flats with a milky mass of calcium carbonate fatal to pelagic

life. Thus the Atlantic corals receive nearly all of their food from the rising tide which flows inward over the flats from deep water, while on the ebb-tide but little food is brought to them.

In the Pacific, on the other hand, the limestone platforms are usually covered with water 15 to 20 fathoms deep instead of 3 to 6 fathoms as in the Atlantic. Moreover, the Pacific submerged platforms are usually less extensive than those of the Bahamas and West Indies and there is less precipitated limestone mud over their bottoms than in the Atlantic. Thus food conditions for corals are apparently better in the Pacific than in the Atlantic, and, as is well known, the growth-rate of such lowly organized forms as coelenterates is chiefly a factor of their food supply.

Using Winkler's method, it was found that among Samoan corals *Pocillopora* consumes about twice as much oxygen in a given time as does *Acropora*, and the latter has a higher rate of oxygen consumption than has *Porites*. *Acropora* and *Pocillopora* live best in the cool, pure, and relatively agitated waters of the seaward parts of the reef-flat, while *Porites* heads are characteristic of hot inner flats or silted regions off the mouths of streams.

For a number of years Professor William H. Longley, of Goucher College, has made a study of the colors and patterns of fishes in relation to their habits and has shown that these colors and color patterns serve in large measure to render the fishes inconspicuous and thus possibly to facilitate their escape from enemies. It seemed advisable that he should extend these studies into the Pacific, and accordingly he spent two months in the Hawaiian Islands, provided with a diving-hood, submarine cameras, and apparatus for color photography. During this visit he was most kindly entertained and aided by Dr. C. Montague Cooke, jr., and by George A. Cooke, esq., the latter taking Professor Longley to his place on Molokai Island, in a coral-reef region favorably situated for these studies. Professor Longley was thus enabled to achieve a decided success in this difficult work, wherein he had often to remain for 4 or 5 hours at a time under water of considerable depth. The details appear in his report published herewith.

The following investigators studied under the Department of Marine Biology during the year 1917-18:

- L. R. Cary, June 18 to September 24, studied the Alcyonaria of the reefs of Samoa and Fiji.
- Ulric Dahlgren, April to June, visited the southern United States for study of luminous organs in insects.
- E. Newton Harvey, September 1917 to January 1918, visited Japan to study the chemistry of the light-producing substances in marine animals.
- William H. Longley, June to September 1918, visited the Hawaiian Islands to study the relation of color and color-pattern of reef fishes to their environment.
- Alfred G. Mayor visited Tobago, British West Indies, Samoa, and Fiji Islands, in the study of the siphonophores of the West Indies, the coral reefs of the Pacific, and the alkalinity of the Atlantic and Pacific Oceans.
- A. L. Treadwell, March 8 to May 8, 1918, visited Tobago to study the Eunicidæ of the coral reefs.

The following papers were published during the year:

- GUDGER, E. W. On spider-webs and spider-web fish-nets. Bull. New York Zool. Soc., vol. XXI, pp. 1687-1690, 1918.
- . The myth of the ship-holder: Studies in Echeneis or Remora: I. Annals and Mag. Nat. Hist., ser. 9, vol. II pp. 271-307, 3 pls. with 9 figs, 1 text fig., 1918.
- HATAI, S. The brain-weight in relation to the body-length and also the partition of non-protein nitrogen in the brain of the gray snapper (*Neomænis griseus*). Proc. Nat. Acad. Sci., vol. 4, pp. 19-21, January 1918.
- McCLENDON, J. F. Diurnal changes in the sea at Tortugas, Florida. Proc. Nat. Acad. Sci., vol. 3, p. 692, Dec. 1917.
- . The effect of stretching upon the rate of conduction in the neuro-muscular network in *Cassiopa*. *Ibid.*, p. 703.
- . Effect of oxygen tension on the metabolism of *Cassiopa*. *Ibid.*, pp. 715-716.
- MAYOR, A. G. Is death from high temperature due to the accumulation of acid in the tissues. Amer. Jour. Physiol., vol. 44, pp. 581-585, Nov. 1917.
- . Formula for rate of nerve-conduction in sea-water. *Ibid.*, pp. 591-595.
- . Report upon the Scyphomedusæ collected by the U. S. Bureau of Fisheries steamer *Albatross* in the Philippine Islands and Malay Archipelago. Bull. No. 100, U. S. Nat. Mus., pp. 175-233, 24 figures, Nov. 1917.
- , 1918, Memoir of William Stimpson. Biographical Memoirs of National Academy of Sciences, vol. 8, pp. 419-433, Portrait.
- , 1918, Navigation illustrated by diagrams. 207 pp.
- HARVEY, E. NEWTON. Studies on bioluminescence, IV. The chemistry of light production in a Japanese astracod crustacean, *Cypridina hilgendorffii*, V. The chemistry of light production by the firefly, VI. Light production by a Japanese permatulid, *Cavernularia haberi*. Amer. Jour. Physiol., vol. XLII, pp. 319-358, 1917.
- . What substance is the source of the light in the firefly. Science, n.s., XLVI, pp. 241-243, 1917.
- . Studies on bioluminescence, VIII. The mechanism of the production of light during oxidation of pyrogallol. Jour. Biol. Chem., vol. XXXI, pp. 311-336, 1917.

*Further Studies on the Chemistry of Light Production in Cypridina, by
E. Newton Harvey.*

During the fall and winter of 1917-18 I spent several months collecting and drying specimens of *Cypridina hilgendorffii*, whose brilliant blue luminescence has been already described in the papers from the Tortugas Laboratory.* The material collected by one man amounted to a volume of 3.5 liters and a dry weight of about 700 grams, representing some 1,225,000 organisms. This is in addition to the material used in experiments carried out in the Zoological Laboratory, Imperial University, Tokyo, where I was given most excellent facilities for research. It gives me pleasure to acknowledge the kindness of Professors Ijima, Yatsu, Watase, and Goto during my stay at the university. I am deeply indebted also to Prof. C. Ishikawa, of the Agricultural College, Tokyo, for assistance in collecting material and for his interest in my work.

In the papers from the Tortugas Laboratory I described the substances photophelein and photogenin, which must be present with water and oxygen to produce light. I find that under the term photophelein I have previously included two different substances. One of these is a body, found only in *Cypridina hilgendorffii*, which oxidizes spontaneously without light production in the air and corresponds to the luciferine found by Dubois in *Pholas dactylus*. It is dialyzable, thermostable, and may be called *Cypridina* luciferin. In the presence of non-dialyzing thermolabile *Cypridina* luciferase (corresponding to my old term, photogenin) it oxidizes *with* light production. *Cypridina* luciferine differs from *Pholas* luciferin in that it can not be oxidized with light production by KMnO_4 , H_2O_2 , with or without hemoglobin or similar oxidizing agents. The other substance is found in many non-luminous animals, is also thermostable and assists in promoting the luciferin-

* Chemistry of Light Production in Luminous Organisms. Carnegie Inst. Wash. Pub. No. 251.

luciferase reaction. For this substance I propose to retain my old term photophelein.

When *Cypridina* luciferin is oxidized no fundamental splitting of the molecule occurs, because the product, which I propose to call oxyluciferin, can be readily reduced to luciferin again. This reduction is brought about under conditions similar to those necessary for the reduction of dyes such as methylene-blue. Indeed, the change luciferin $\longrightarrow$ oxyluciferin appears to be very similar to the change leuco-methylene blue $\longrightarrow$ methylene blue. Oxyluciferin can be reduced to luciferin, which will again give light with luciferase by the reductases of muscle-tissue, liver, etc., or by bacteria; by Schardinger's enzyme of milk; by H_2S or the nascent hydrogen from the action of acetic acid on magnesium; and by palladium black and sodium hypophosphite, all well-known reducing methods. The reaction luciferin $\longleftrightarrow$ oxyluciferin is a reversible one and reduction of oxyluciferin no doubt occurs in animals which burn luciferin within the cell, thus tending for conservation of material.

TABLE 1.—*Properties of photogenic substances.*

Property.	Luciferase.	Luciferin.
<i>Salting out:</i>		
By saturation NaCl	Not precipitated.....	Not precipitated.
By half saturation MgSO_4	Do.....	Do.
By saturation MgSO_4	Nearly completely precipitated.	Partially precipitated.
By saturation MgSO_4 and acetic acid.....	Do.....	Do.
By half saturation $(\text{N}_2\text{H}_4) 2\text{SO}_4$	Slightly precipitated.....	Not precipitated.
By saturation $(\text{NH}_4)_2\text{SO}_4$	Completely precipitated....	Nearly completely prec.
By saturation $(\text{NH}_4)_2\text{SO}_4$ and acet. acid.....	Do.....	Do.
<i>Solubility in:</i>		
Methyl alcohol.....	Insoluble.....	Soluble.
Ethyl alcohol.....	Do.....	Do.
Ethyl alcohol, 90 p. ct.....	Do.....	Do.
Ethyl alcohol, 70 p. ct.....	Do.....	Do.
Ethyl alcohol, 50 p. ct.....	Slightly soluble.....	Do.
Propyl alcohol.....	Insoluble.....	Do.
Isobutyl alcohol.....	Do.....	Fairly soluble.
Amyl alcohol.....	Do.....	Slightly soluble.
Benzyl alcohol.....	Do.....	Soluble.
Acetone.....	Do.....	Fairly soluble.
Acetone, 90 p. ct.....	Do.....	Soluble.
Acetone, 70 p. ct.....	Slightly soluble.....	Do.
Acetone, 50 p. ct.....	Fairly soluble.....	Do.
Ethyl acetate.....	Insoluble.....	Do.
Ethyl propionate.....	Do.....	Fairly soluble.
Ethyl butyrate.....	Do.....	Do.
Ethyl valerate.....	Do.....	Slightly soluble.
Ethyl nitrate.....	Do.....	Very slightly soluble.
Glycerine.....	Do.....	Soluble.
Glycol.....	Do.....	Do.
Ether.....	Do.....	Insoluble.
Chloroform.....	Do.....	Do.
Carbon disulphide.....	Do.....	Do.
Carbon tetrachloride.....	Do.....	Do.
Benzol, toluol, xylol.....	Do.....	Do.
Petroleum ether.....	Do.....	Do.
Anilin.....	Do.....	Do.
Glacial acetic acid.....	Do.....	Fairly soluble.

In the firefly, for instance, it is possible that reduction occurs in the period between flashes, while we know that oxidation occurs during the flash of light. Dilute alkali favors oxidation and dilute acid favors the reduction.

So far as I have been able to determine, luciferin and oxyluciferin have identical chemical properties. Neither are digested by the enzymes: malt diastase, ptyalin, yeast, invertase, pepsin, trypsin, steapsin, amyllopsin, rennin, erepsin, urease, or enzymes occurring in the water-extracts of dried spleen, kidney, or liver. Of the above enzymes tried, luciferase is destroyed only by pepsin (probably), trypsin, erepsin, and something in spleen and liver extract. Further properties of *Cypridina* luciferin and *Cypridina* luciferase may be noted from the following table:

TABLE 2.—*Properties of photogenic substances.*

Property.	Luciferase.	Luciferin.
<i>Alkaloidal reagents:</i>		
Phosphotungstic acid.....	Completely precipitated....	Very nearly completely precipitated.
Phosphotungstic and acetic acid .....	.....	Do.
Phosphotungstic acid and HCl.....	.....	Completely precipitated.
Formic acid.....	Nearly precipitated.....	Nearly completely precipitated.
Formic and acetic acid.....	.....	Do.
Formic acid and HCl.....	.....	Do.
Picric acid.....	Nearly completely precipi'd.	Not precipitated.
Picric and acetic acid.....	.....	Do.
Picric acid and HCl.....	.....	Do.
K ₄ Fe(CN) ₆ and acetic acid.....	.....	Do.
<i>Heavy metal salts:</i>		
Basic lead acetate.....	Completely precipitated....	Not completely precipitated.
Neutral lead acetate.....	Nearly completely precipitated.	Do.
Neutral lead acetate and acetic A. ....	.....	Do.
Mercuric chloride.....	Not precipitated.....	Do.
Mercuric chloride and acetic A. ....	.....	Almost completely prec.
Uranyl nitrate and acetic acid.....	.....	Not completely prec.
<i>Acids and alkalies:</i>		
KOH.....	Not precipitated.....	Not precipitated.
NH ₄ OH.....	Do.....	Do.
Acetic acid.....	Do.....	Do.
Carbonic acid.....	Do.....	Do.
Trichloroacetic acid.....	Do.....	Do.

There is no doubt that luciferase is a protein. All its properties agree with those of the albumins.

Luciferin, on the other hand, is not digested by proteolytic enzymes, is dialyzable, almost but not completely precipitated by saturation with (NH₄)₂SO₄, and is soluble in absolute alcohol, acetone, and some other organic solvents, but not in the strictly fat-solvents like ether, chloroform, and benzol. There are, however, certain CO-NH linkages which are not attacked by proteolytic enzymes and some peptones soluble in absolute alcohol, so that these two characteristics do not bar it from the group of proteins. Luciferin, in fact, has many properties in common with the proteoses and peptones and may be provisionally placed in a new group of natural proteins on the borderland between the proteoses and peptones.

Although the luciferins and luciferases of different luminous animals are certainly similar substances, they are not identical. Through the kindness of Professor Dubois I have obtained some luminous organs of *Pholas dactylus* preserved in sugar. *Pholas* luciferin will give no light with *Cypridina* luciferase and *Cypridina* luciferin will give no light with *Pholas* luciferase. No doubt these two forms are too distantly related for the interaction of the luminous substances. The specificity of different luciferins, especially in relation to the color of the light produced, offers a most interesting and important field for subsequent research, and I hope to be able to present more data on this subject in the near future.

A Study of Luminous Insects, by Ulric Dahlgren.

The writer spent the months of March and April 1918 in the South, studying and collecting luminous organisms. Starting from New York on a Mallory steamer for Galveston, very little of value was seen at sea. Varying numbers of luminous plankton appeared and part of each night was spent in observing and attempting to identify them. The green glow of ctenophores was easily distinguished from the silvery light of *Noctiluca* and other dinoflagellates. One interesting observation was made at 10^h30^m p. m. in the waters of the Gulf of Mexico. Standing at the rail, the slap of a porpoise's tail was heard as he discovered the steamer and decided to move in by the bow from a distance of about 200 yards off the beam pretty well aft. Looking quickly toward the sound, the animal was seen (the night was dark) as a moving luminous body with a diminishing trail of several yards. Moving at a speed of between 15 and 20 knots, he passed in a long, slightly curved path to a position just under the bow, where he played for about 5 minutes and then suddenly disappeared. The whole episode so resembled the approach of a torpedo that several people who saw it drew back from the rail and two women screamed, although several called out "porpoise."

Landing at Galveston and proceeding to Houston, it was found that a very dry season had prevented the appearance of nearly all insects; also that it was too early for fireflies. A number of trips with local collectors, by both day and night, failed to show any luminous forms except some collembolids. The same was true of a trip south nearly to Brownsville, where some collembolids and a few larvæ of the common firefly, *Photuris pennsylvanica*, were all that was found.

Better results were obtained at Beaumont, Texas, where a few of some common forms were on the wing and luminous collembolids were also found; also some luminous earthworms. The finding of luminous earthworms and collembolids here and at other localities and the continual observation of them while demonstrating their light were important, because up to the time of this trip their organic light production was an open question with some zoologists. Such reports as had been made of the phenomenon were published in obscure journals or were contradictory. The writer has followed up verbal or published reports by Atkinson, Barber, and McDermott very carefully and has repeatedly proven that both the collembolids (some species) and earthworms (*Microscolex*) do flash or glow with an autogenous organic light in response to well-known stimuli that are used to prove the presence of such light in other well-known luminous forms.

Several swamps and localities were then visited between Beaumont and New Orleans and a week was spent in the swamps and inland waterways south of New Orleans. In all of these regions the fireflies were beginning to appear and the mating habits were studied, especially the uses of the light as

a mating signal. Luminous collembolids were collected in every region and one specimen of luminous earthworm, but no *Phengodes*. Several luminous mycelia of fungi were obtained in decaying wood.

In Alabama the season was advanced and very rich material was found. A firefly (*Phausis*) was abundant, which had previously been collected only once. Specimens were presented to the U. S. National Museum, in which there were only three poorly preserved examples. This form is interesting in that it has a very distinctly blue light. The adult female is a white wingless grub with multiple lights on all surfaces and the light-organ is of the simple two-layered type, without "ovals," that is found in the Japanese, Chinese, and Eastern Russian species that have been examined by the writer. In Tuscaloosa luminous collembolids were collected and a number of fine larvæ and one male pupa of a *Phengodes* of unknown species. These were turned over to the U. S. National Museum for identification or naming and the lighting habits of the larvæ and pupa were studied. Arrangements were made for the collection and shipment of other specimens, especially adults in the later seasons.

In Tennessee many fireflies were studied and luminous collembolids were collected; and in Virginia, where some good luminous fungi were also found.

The neighborhood of Washington, D. C., was explored in company with Mr. H. S. Barber, of the U. S. National Museum, and Mr. F. A. McDermott; many luminous insects were studied, especially the firefly *Pyrractomena borealis*, whose larva was pupating on the trunks of trees at some distance above the ground. The type locality for luminous collembolids was visited and these interesting insects were found in large numbers.

Habits and Coloration of Hawaiian Brachyura and Fishes, with a note on the Possibility of Submarine Color-photography, by W. H. Longley.

Work in Hawaii was undertaken with the idea of testing conclusions previously drawn from a study of West Indian fishes, whose coloration and habits it was proposed to compare with those of other species widely removed from them geographically. It was also hoped that opportunity might present itself for a renewed trial of the possibility of submarine color-photography.

Immediately after arrival in Honolulu on June 24, a week was spent in the effort to find a place upon the island of Oahu suited to the needs of my investigation. Molokai was then visited and what proved to be permanent quarters were taken up at Pukoo, near its eastern extremity, a point perhaps better fitted for my purpose than any other within the group.

In this connection it is a pleasure to acknowledge my indebtedness to Dr. C. Montague Cooke, jr., of the Bishop Museum, Professor William Alanson Bryan, of the College of Hawaii, and Mr. Allen Herbert, Minister of Agriculture under the old regime, for advice and invaluable assistance in making my preliminary survey of the islands; to Mr. George A. Cooke for his kindly interest in locating me upon Molokai; to Judge C. C. Conradt and Mrs. Conradt for their hospitality during my stay in Pukoo; to Mr. Frederick A. Potter, of the aquarium in Honolulu, for many professional courtesies; and to Mr. A. W. Collins, manager of the Pioneer Mill, Lahaina, and Captain John H. Wilson, of Kamalo, for generous aid at essential points.

The flat between the shore and the margin of the fringing reef at Pukoo averages about half a mile in width and is covered at different points by water varying from a few inches to 6 feet or more in depth, according to the stage of the tide. It is comparatively free from fine sediment washed down from the land to make the water turbid, and is covered profusely in places by spongy banks of branching *Porites*, which are frequented by fishes and

are intersected by channels 6 or 8 feet deep, rendering their various parts easy of access. There are also large holes which may be several hundred yards in diameter and 20 feet deep, which, like natural aquaria, usually contain representatives of 30 or 40 species of fishes, sometimes available for study when rough weather renders it impossible to work to advantage elsewhere. When both sea and tide are high, however, no place is so quiet and free from turbidity that one may work under water with much profit.

At a few points the edge of the main reef was accessible for a portion of the time, yet during my stay in Pukoo (from July 3 to August 21) there was no day on which the trade wind diminished sufficiently to permit free examination throughout its length of the rugged bottom just beyond the breakers where species most abound. How much of interest lies there may be inferred from the fact that 50 species of fishes, represented in all by many hundreds of individuals, were seen at one station within an hour and within a radius of little more than 50 feet.

Beyond the breakers the bottom is essentially smooth rock, bearing upon it sparsely scattered colonies of branching coral, and sloping gradually out to deep water. It may be bare, covered by loose white sand, or by a thick, short turf of algæ, long, freely waving *Sargassum* or *Dictyota*, for example, having been observed at only a few places on the inner flat. Fishes do not appear upon it by day in large numbers in proportion to its area. This region was usually difficult to reach through the breakers with a small boat, but since others more accessible were sufficiently rich and varied to provide profitable employment for a longer period than was available for their study, the limitations prescribed by the weather were not as oppressive as might otherwise have been the case.

Advantage was taken incidentally of the opportunity to make a few observations upon *Brachyura*.

Ocypoda ceratophthalma (Pallas) burrows in sandy beaches between tide-marks. It comes out most freely by night, except perhaps on unfrequented shores, where it is said to be less distinctly nocturnal in habit. The burrows constructed by the creatures at different stages in their development vary in form. The youngest dig simple vertical holes in the sand. Those of intermediate size usually incline their main tunnel toward shore and from a point midway in its length carry up a vertical shaft or chimney which they may or may not leave closed at the surface, and in which they commonly rest, as *O. arenaria* of the Atlantic coast of America and the West Indies does under like conditions. The burrows of the adults of *O. ceratophthalma* are, however, upon the whole rather more elaborate than those of *O. arenaria*. Some are like those constructed by crabs of medium size, but lack the vertical chamber. Others descend spirally for about one complete revolution before turning more or less sharply down and out to a point from 1 to 2½ feet beneath the surface.

The course of the spiral in some burrows is clockwise, in others the reverse. The first are dug by crabs with the larger chela on the right side, the second by those which have it on the left. Both types of burrows are so firmly stopped up with sand from the inside by their occupants, at a point about as far down as the end of the first complete turn of the spiral, that one is very apt to fail to follow the burrow farther, since the hardness of the bulkhead may be little less than that of the undisturbed sand. When they are uncovered both right-handed and left-handed individuals are found in the bottom of the burrow with the large claw outermost.

Sometimes a burrow is occupied by more than one individual. A large hole with a small chimney had two tenants, of which the smaller in the upper

compartment was probably the interloper. A single burrow in one instance contained three living and uninjured crabs. In this case an accessory pocket at one side below contained a small female, while the large terminal chamber held an adult male.

O. ceratophthalma is found both on shell or coral beaches of white sand and on the dark beaches formed from disintegrated lava. Its color in the two cases accords very well with that of its surroundings. Upon the light-colored beaches, so far as the dorsal surfaces of the adults are concerned, it is of their light hue, with or without a few comparatively small maroon blotches on the cardiac region. Upon the dark beaches, on the contrary, it is of an almost uniform dark reddish brown. The younger individuals show corresponding differences in shade, but are variously mottled rather than uniformly colored. If tested by placing them in black and in white dishes they show speedily that they possess capacity to change their shade in the direction of that of the substratum on which they stand. The conformity of the species to its environment in nature, therefore, seems capable of simple explanation. It may be added parenthetically that *Thalamita integra* (Dana) and *Portunus sanguinolentus* (Herbst) are also changeable in shade, a statement particularly applicable to the former.

In my last report it was stated that the possibility of successful submarine photography in colors had been established by experiments performed during the summer of 1917. It must apparently be added, however, in view of this summer's results, that an *accurate* photographic record showing in color the nature of the environment to which tropical reef-fishes possess such marked power of color-adaptation may not be obtained by use of the same screens as are used for color-photography in air. When the first report was made it was supposed that the failure to secure accurate reproduction of the different color values in the field of the lens was due to the use of another screen than was made by the manufacturer of the plates used. In the present instance essentially the same defects appear in the developed plates, although it was demonstrated in advance that in air the adjustment of screen to plates was perfect. The difficulty seems to lie in the fact that differential absorption of light rays of different wave-lengths occurs in their passage through the water. The light which falls upon a particular color-screen in air and in water is not composed, therefore, of light rays of the same sorts in the same proportions in the two cases, and its components can not be reduced to equality of influence upon the sensitive plate in both media. It is necessary that a special screen stopping more of the rays of shorter wave-length than is required in air should be used in submarine color-photography, and even then the best results at a given depth and time could probably be obtained by its use at only one distance from the object photographed.

About 90 species of fishes were seen during the summer, of which several are either new to science or hitherto unreported from the Hawaiian Islands. Some, however, were encountered rarely, so that those under daily observation scarcely exceeded half the total.

As is the case with the tropical fishes of every region, the colors of many Hawaiian species are inadequately described in systematic works, since these are concerned almost wholly with the appearance of dead specimens. It may be mentioned in passing that what is probably the best existing record of the form and coloration of a group of tropical fishes of comparable numbers is embodied in the series of painted casts of more than 340 species prepared by Mr. John W. Thompson for the Bishop Museum, Honolulu. Yet even this notable series, in spite of the fact that in a number of instances several color-phases of a single species are represented, fails to do complete justice to its subject.

The family of the Labridæ is rich in Hawaiian genera and species, to which many of the observations mentioned below refer. Not the least interesting among them are the hatchet-faced genera, *Novaculichthys*, *Cymolutes*, *Iniistius*, and *Xyrichthys*, which commonly escape pursuit, when danger becomes too urgent, by darting beneath the surface of loose sand, where the difficulty in locating them indicates they possess no mean power of movement. In this highly specialized reaction they simply exhibit in extreme form a type of behavior common within the family under certain circumstances, for both in the West Indies and in Hawaii many labrids bury themselves in the sand at night. To West Indian forms in which this habit has been noted and to species of the genera enumerated above the following may be added on the strength of observations made in the aquarium at Honolulu: *Cheilio inermis*, *Coris venusta*, *Julis eydouxi*, *J. lepomis*, *J. pulcherrima*, *Thalassoma balliewi*, and *T. duperrey*.

Special attention was paid to analysis of the diversity of habit which appears within the families of Mullidæ and Teuthidæ, both rich in local forms. For the point has been made that differences in habit between related species are often so slight that differences in color with which they may be associated can not be explained by correlation with them. In the case of the fishes here mentioned such observations as were possible under existing conditions go far toward showing that (providing their habitats are accessible), however like one another they may appear in other respects, distinct differences in habit exist in general between any two species strikingly different in coloration.

It is noticeable that color is correlated with habit upon the same terms in the West Indies and in Hawaii. This is suggested by the fact that there are such pairs of species as *Abudefduf saxatilis* and *A. abdominalis* of the respective regions, or *Eupomacentrus fuscus* and *Pomacentrus jenkinsi*, which are so like one another in appearance that with one in sight and only the memory of the other in mind it is impossible to cite any difference between them, except in geographical distribution.

Approaching the same subject from another point of view, it is to be noted that blue-gray seems as definitely correlated in one place as in the other with the habit of floating high in the water. The case is beautifully exemplified by comparing *Abudefduf abdominalis* with *A. sordidus*, both Hawaiian species. Like *A. saxatilis*, the former rises clear to the surface on occasion and commonly swims at high levels. *A. sordidus* is by comparison a bottom species and matches the blue-gray in the pattern of the other by more or less dusky olive. In color it is much like *A. taurus* of the West Indian region, which I have seen too rarely for comparison at length in respect to habits, but concerning which my experience contains nothing inconsistent with the assumption that it too is much more closely confined to the bottom than *A. saxatilis* is.

Another pair of Hawaiian species, between which the same difference in habit is coupled with corresponding difference in coloration, includes *Chromis ovalis* and *C. elaphrus*. The former rises freely to the upper levels in the water and as an adult is distinctly blue-gray without markings of other colors; the latter, within the limits of my observations, and I have seen many individuals of the species, always stays near the bottom, usually a rocky one, and slips in and out of tiny crevices with great agility. It is pale olive in coloration, becoming more yellow on the fins, and across the eye it has a vertical black bar the width of the pupil.

The red genera, *Myripristis*, *Holocentrus*, *Priacanthus*, and *Amia*, represented by *M. symmetricus*, *H. diadema*, *H. microstomus*, *P. alalaua*, and *A.*

menesema, agree with their West Indian relatives in feeding by night and hiding in coral or rock crevices during the day. The red color of this group is correlated, then, both in the Atlantic and in the Pacific, with the habit of living in dim light.

It is interesting to note in this connection that *Pseudupeneus porphyreus* and *Mulloides auriflamma*, two of the Mullidæ which feed by night and school about rocky cavernous places by day, have each a red phase which they assume when they pass from the open into the deep shadow under overhanging ledges. On the other hand, *A. menesema*, which is more retiring, has a gray phase which I have seen it display when near the bottom over bare sand in the mouth of a small cave, while other individuals higher up in the shadow were reddish brown. It may be noted incidentally that the visibility of this color is very low under the conditions stated, much lower than yellow, for example. For a fish strongly marked with yellow may be seen far back in the cavern, when a red one much nearer at hand and almost in the direct line of vision may be perceived with the greatest difficulty.

Julis gronovii seems an exception to the general rule that there are no truly red fishes of the shallower tropical waters which are not nocturnal, for in spite of its clearly defined white markings it is largely of a vivid red color which it has no evident power to suppress under any condition. It is of interest, then, to note that this is apparently the young of *J. pulcherrima*, for all intermediate forms between the two are seen upon the reefs, but not so commonly that it was possible to secure a series for the purpose of making the point absolutely certain. However, little is left to be desired when in individuals scarcely beyond arm's reach one may see that the characteristic markings of *gronovii* become fainter and fainter as the fishes increase in size, while one after another of the distinctive features in the coloration of *pulcherrima* comes into being until the perfect form is attained. The transformation is no greater and the stages in the transition no less easy than in the case of *Thalassoma bifasciatum* and *T. nitidus*, to which attention has been called in a previous report. So it still seems probable that in spite of the comparatively common occurrence of a red coloration among fishes, diurnal species whose red is of more than a transient character are almost or quite absent from shallow tropical waters.

Hawaiian fishes possess to a marked degree capacity to change their coloration as their surroundings or their activities vary; 27 species, representing 22 genera and 9 families, were observed to alter color in one or more respects as their relation to their environment changed. To these should perhaps be added 5 others concerning which the evidence is not quite so clear; 22 of the 27 effected adjustments in shade; 13 changed their pattern; and 11 changed their color in a definite manner under stated conditions.

Transverse bands or longitudinal stripes may distinguish alternative color-phases of a single species. When such is the case the banded pattern tends to mark fishes resting near the bottom and the striped one those in motion. Though *Coris venusta*, *Pseudupeneus pleurostigma*, and *P. porphyreus* show comparable changes, this is most clearly illustrated among Hawaiian fishes by *Cheilio inermis*, in the coloration of which gray, brown, olive, and yellow replace one another from moment to moment as these colors happen to predominate in its environment; and if one has a score of specimens under observation at once in their brown phases in a sargassum patch, it is very clear that each momentary pause or trifling advance is closely followed as a rule by the change from stripes to bands, or vice versa. Self-color phases, however, may also appear during motion and are of hues dependent upon the color of the surroundings.

The color changes of *Chaetodon miliaris* and *Callyodon ahula* are very suggestive. The former is a yellowish butterfly-fish whose most striking marking of any other color is its vertical, black, ocular band; the latter, a parrot-fish, whose young, especially, appear in many color-phases. Both the yellow and the black of *Chaetodon* fade when the fish leaves the reef and moves out over pale, fine sand. The same is true when it rises a yard or more from the bottom. This species is the first in which a color-change dependent upon its vertical movement was definitely noted, but mature specimens of the black *Dascyllus albisella* were later seen putting off most of their dark color as they floated higher and higher above the bit of rock or coral over which they might have taken their station. So changes in coloration may occur in fishes as they move from one point to another a few feet distant either in the horizontal or vertical plane. But if such is the case, and if in addition the greater number of observed changes in coloration tend, to all appearances, to reduce the visibility of the individuals displaying them, it seems, in view of the present state of our knowledge, that the nuptial colors of fishes should possibly be considered a reflection of more or less distinct and temporary change of habit or habitat, rather than mere concomitants of increased vigor or products of sexual selection, as many have supposed.

Young specimens of *C. ahula*, about 3 inches in length, were common on the reef flats at Pukoo and are notable in this connection for one thing alone. As a school of these fishes passes, for example, from a bottom covered by small fragments of dead gray coral to another covered by larger pieces of the same material, almost all will probably turn from a mottled gray to very dark brown, which at present I am obliged to interpret as a response to the greater extent and intensity of the shadows beneath them in the second instance. But if certain creatures are capable of masking themselves temporarily in shadow colors, and if the ocular stripe of *Chaetodon*, to which reference has already been made, is a "shadow-picturing" mark, as it may be, it seems very plausible to say that permanent dark lines, spots, or larger areas in the patterns of butterflies, for example, may have the same significance.

There is no group of animals in which species capable of changing color so abound as among fishes. There is, then, no other group in respect to which the biological significance of animal coloration lies so open to testing by controlled observation and experiment. It is, therefore, of interest that as knowledge of the color reactions of unconfined fishes continues to accumulate, the interpretation which it seems necessary to place upon the color of higher animals in general departs more and more widely from those generally accepted.

Studies on Alcyonaria in the Pacific Ocean, by Lewis R. Cary.

A. GROWTH-RATES OF SOME ALCYONARIA AT PAGO PAGO, AMERICAN SAMOA.

The specimens of Alcyonaria of which the growth-rates were studied were first measured in April 1917. All of them were left undisturbed in their original location on the reefs about Pago Pago Harbor. The second measurements were made in July 1918, so that about 15 months had elapsed between the times when the two measurements were made.

Although six species of Alcyonaria are found rather commonly on the reefs about Tutuila, measurements of only four were recorded, since these make up by far the most important element in the alcyonarian fauna. In the order of their importance as contributors to the reef limestones in this region the four species recorded are: *Lobophytum (Alcyonium) rigidum* Dana,

Lobophytum (Alcyonium) confertum Dana, *Sarcophytum glaucum* Dana, and *Alcyonium flexile* Dana. *Lobophytum rigidum* grows most abundantly over the vertical reef edge, where it covers up and causes the death of the more slowly growing stony corals, so that the increase in area of colonies of this alcyonarian is an important factor in the ecology of the reef border, where at present by far the most important coral-limestone formation is taking place. In making the comparison of areas the perimeter of a colony at each measurement was taken as the circumference of a circle and the resulting areas were compared. In practice, in almost every instance the outline of the base colony was by no means a true circle, so that the ratios given are necessarily inexact.

Lobophytum confertum, although most commonly found on the horizontal reef surface, also frequently overgrows some of the stony corals upon which it has found a place of attachment. Large continuous colonies of this species are seldom found, because (as time goes on) the original mass becomes broken up into an increasingly large number of small units. A relatively large barren central area is commonly formed in old colonies and this barren area increases with the age of the colony, which apparently lives on for years in the form of scattered small units.

The increase in area of the two other species measured is a less important factor, but individuals of either one of them may become the dominant element on any protected reef area.

The growth records for the four species mentioned above are briefly summarized in the following table:

Species.	Number measured.	Average increase in linear dimensions along chief axes.	Increase in area.		
			Min.	Max.	Mean.
<i>Lobophytum rigidum</i>	22	1 : 1.381	1 : 1.10	1 : 3.59	1 : 2.35
<i>Lobophytum confertum</i>	33	1 : 2.473	1 : 1.08	1 : 102.0	1 : 13.49
<i>Sarcophytum glaucum</i>	25	1 : 1.396	1 : 1.05	1 : 10.71	1 : 3.98
<i>Alcyonium flexile</i>	27	1 : 1.478	1 : 1.00	1 : 16.02	1 : 6.56

Since the two first-mentioned species form at the base of the colony solid spicule rock which becomes exposed as the soft tissues die and disintegrate at this region, their linear measurements do not give a reliable indication of the amount of limestone that they have secreted. In other forms, however, from which the spicules are not released until the death of the colony, the increase in size has a direct relation to the amount of spicules formed within a given time. Specimens of which the weight as well as the dimensions were recorded were planted on the reef at Pago Pago and at Suva Harbor (Fiji) during the past summer.

The alcyonarian fauna of Tutuila differs so greatly from that of the western Atlantic that no comparison between growth-rates which could have any value can be made on the basis of the data obtained in my studies in the two regions.

B. THE RESPIRATION RATES OF SOME SAMOAN ALCYONARIA.

The respiration-rates of the four species of Alcyonaria mentioned above do not conform to the order of activity of their growth. *Alcyonium flexile* has the highest oxygen consumption at 82.8 c.c. O₂ per kilogram of fresh

weight per hour. *Lobophytum confertum* stands second in the list, with an oxygen consumption of 55.424 c.c. per kilogram per hour. *Lobophytum rigidum*, although the first to succumb to increased temperature, stands third in the order of rapidity of respiration, with an oxygen consumption of 42.40 c.c. per kilogram per hour. The remarkably low oxygen consumption of 21.30 c.c. per kilogram per hour shown by *Sarcophytum glaucum*, when estimated on the basis of its fresh weight, will be in part explained by the fact that this species contains only about 6 per cent by weight of spicules. In contrast to this low spicule content, both species of *Lobophytum*, however carefully separated from their basal spicule rock, will contain nearly 20 per cent of spicules, so that comparisons based upon the fresh weight of the different species would of necessity cause the oxygen consumption of the last-mentioned forms to appear much greater.

Alcyonium flexile, which has the highest oxygen consumption, contains only a slightly higher proportion of spicules than *Sarcophytum*, so that this explanation is inadequate to satisfactorily account for the observed differences. As bearing upon this point, it may be mentioned that in my studies on the respiration of some Alcyonaria at Tortugas, it was observed that those species that have the greatest area in proportion to their weight have a far more active respiration than do the less finely divided forms. When arranged upon this basis, the Samoan species show a close agreement between the area of surface for a given unit of weight and their rate of oxygen consumption.

C. THE STRUCTURE OF THE FRINGING CORAL REEFS OF PAGO PAGO HARBOR.

In order to determine the origin of the limestone making up the Samoan coral reefs, the structure of the reef on the south side of the cove off the village of Utelei, in Pago Pago Harbor, was studied in detail, first by making a determination of the character (origin) of the surface rock at intervals of 10 feet along a line across the reef; secondly, by means of boring made with a Davis calyx core-drill.

When collecting the surface samples material was dug up in a number of instances from a depth of 4 feet. At 83 of the 95 stations where examinations of the surface material were made, some portion of the square yard of surface over which samples were taken was found to be composed of rock of alcyonarian origin. Near the shore, where sand is abundant and very few living organisms are to be found, "nodules" of *L. confertum* spicules were obtained on digging to a depth of not more than 18 inches. On the lithothamnium ridge, which was about 60 feet wide at this point, only one sample of spicule rock was found, and that at the base of a living colony of *L. rigidum* in the breakers. At every station except one in the distance between the sandy barren area near shore and the lithothamnium ridge some spicule rock was found. Numerous areas barren of all living organisms were found surfaced almost entirely with spicule rock. Observations at many other points on the surface of this reef show that at least 75 per cent of its surface is, or has been very recently, covered with *Lobophytum* for a period of sufficient length to allow of the formation of spicule rock from a fraction of an inch to several inches in thickness.

At the northwest corner of this reef an area several acres in extent is thickly carpeted with *L. confertum*, the continuous skeletons of which extend for several feet below the surface of the reef. During the long-continued growth of these colonies the living tissue has died in many places, so that the skeletal mass has become tree-like in form. Each of the branches of the skeleton is at present crowned by a mass of living tissue, while at its base the skeletal mass may be attached to the solid substratum by a single slender stalk.

Of the stony corals growing on the surface of this reef a massive *Porites* is the most important single element. On the sand-covered inner portion of the reef this species is the only madreporarian that is at all common. At the reef edge a mushroom-shaped *Acropora* is abundant near the surface of the water, while at greater depths a *Porites* with coarse branches constitutes almost the entire madreporarian fauna. In a few very restricted areas on the reef surface a branching *Acropora* (like *A. muricata*) is the dominant element. Fragments of the skeleton of this species are widely dispersed from the place of their origin by the very strong currents and wave-action, so that they make up a characteristic factor in the loose material on the surface of the reef.

The evidence of the structure of the fringing reef at Utelei, Pago Pago Harbor, as determined by the borings, was very incomplete. The thickness of the reef was found to be 121 feet at a point 575 feet from the shore; the character of the material encountered was such that a satisfactory core was obtained from very limited areas only. On the other hand, the contents of the "calyx barrel" (a cylindrical pipe open at the top, of the same diameter and length as the core barrel which extends upward from the upper end of the latter) gave a fairly accurate record of the nature and disposition of the material through which the drill was cutting at any time. Through a greater part of the depth of the boring the material encountered was made up of loosely branching "coral" with the interstices between the branches filled with calcareous sand which washed out of the bore-hole under the pressure of water necessarily used, so that the coarser material caught in the calyx barrel represented in many instances a minor portion only of the mass actually removed in making the boring. When solid material, such as a massive *Porites* head, was encountered a continuous core was always obtained. In these few instances the fragmented finer corals were confined in the upper parts of the core barrel and brought to the surface.

For a depth of about 6 feet from the surface the fringing reef was composed of a solid layer of *Lobophytum* spicules and *Porites* skeletons. Immediately below this hard surface crust was a region, some 45 feet in depth, where the sand was so preponderant a factor that the use of a casing was necessitated to prevent the filling of the bore-hole each time the drill was withdrawn. From this depth to the point where the solid substratum of lava rock was encountered, at a depth of 121 feet, the general character of the limestone was that of a rather loosely branching framework of solid material, in which was lodged a greater or less amount of coral sand. Although nowhere abundant enough to fill up the bore-hole, some loose sand (as yet apparently unchanged chemically) was present, except in the few places where solid coral heads were encountered.

The material obtained from the boring had in general undergone remarkably little change in appearance. Many of the madreporarian corals retained the detailed structure of their calices. Indeed, the section of a *Cyphastrea* head brought up in the core barrel from the depth of 118 feet could not be distinguished, as regards its structural details, from a section through a specimen on the reef surface to-day. At some levels the fragments of the coarsely branched *Porites* had undergone a chemical change, in the course of which their substance had become darkened except for a small central axis, roughly a centimeter in diameter, where the original appearance had been retained. The calyces were no longer complete, or sometimes hardly recognizable on this material, and the diameter of the stems had been considerably increased by the addition of extraneous material over their surfaces. Such transformed

material was brought up from different levels below 50 feet, and the corals from near the bottom of the reef did not have the appearance of having undergone any more extensive chemical changes than had that from considerably less depth.

The samples of this material shipped to Princeton for more careful examination and analysis have not as yet been received, so that no data on the extent and character of the changes that the coral has undergone are available except those obtained in the hasty examination made when the specimens were taken from the drill and packed for shipment.

The deepest boring (125 feet) was made at a point a little more than half (0.57) of the distance from the shore to the reef edge, so that by itself it would afford no evidence on whether or not the fringing reefs about Pago Pago Harbor are built up on the sloping sides of the old crater or upon a platform cut into the shore in the Tertiary era. When the results of our borings are considered in connection with the fact that when constructing the foundation for the cold-storage plant of the United States naval station at Pago Pago (which is situated within 100 feet of a lava cliff) a depth of 116 feet was reached before a solid substratum was found, it appears more probable that a fairly level platform exists beneath these reefs than that they have been formed on the natural slope of the shores.

ALCYONARIAN FAUNA OF REEFS ABOUT VITI LEVU.

The alcyonarian fauna of the reefs about Viti Levu is very much richer in species than that of the Samoan reefs. *Tubipora* and other forms with a massive skeleton are abundantly represented. Several undescribed forms, showing in different degrees the transformation from the *Sarcophytum* type to that of *Lobophytum*, occur over many of the reefs where with *Xenia* and nephthyids they cover immense areas of bottom on the inner sides of the barrier reefs, which in the region about Suva lie parallel to the general shoreline at a distance of not more than a mile. On many of these reefs the Alcyonaria appear to constitute an even more important element of the present reef fauna than on the Samoan reefs. In the elevated Tertiary limestones, found in several places about Suva Harbor, the skeletons of an alcyonarian resembling *Heliolites* was found in a recognizable condition perhaps more commonly than the remains of any other coelenterate.

Although in the short time at our disposal in this region no extensive study of the reefs could be attempted, specimens constituting a comprehensive growth series of the most important forms were photographed, weighed, measured, and cemented out on the reefs near their original locations.

THE OXYGEN CONTENT OF THE SURFACE-WATER OF THE PACIFIC OCEAN.

The following observations on the oxygen content of the surface-water in the Pacific Ocean were made on voyages from San Francisco to Pago Pago, June 19 to July 1, 1918; from Apia, Samoa, to Suva, Fiji, August 9 to 13, 1918; from Suva to Vancouver, British Columbia, September 6 to 19, 1918; and in Pago Pago Harbor during July 1918. Although the data have not as yet been carefully compared with the calculated solubilities of oxygen in sea-water of like temperatures and salt content, it seems probable that the amount of dissolved oxygen in Pacific surface-water approximates very closely the expectations founded upon this basis. The only marked departure from this apparent agreement was observed in the region 5° north of the equator, where an easterly current was encountered. The oxygen content of the water in the easterly current was considerably higher than that of water of the same

temperature from a relatively short distance away, but where the normal westerly drift prevailed. The higher oxygen content of this water was associated with a lowered salinity and hydrogen-ion concentration, as noticed by Dr. A. G. Mayor in another place in this Year Book. As was observed by McClendon for the water of the western Atlantic, the oxygen content was slightly higher at midday than at night or in the early morning. A slight difference was also found between bright sunny and cloudy days, dependent no doubt on the differences in photosynthetic activity of the minute planktonic algæ.

The oxygen content of the water in Pago Pago Harbor varied greatly at different times and in different locations. At the end of Blacklock's dock, near our laboratory, at the inner end of the harbor, the range was from 3.503 c.c. to 6.11 c.c. per liter. The higher content was coincident with the presence in the water of immense numbers of dinoflagellates, to the photosynthetic activity of which the increased oxygen content of the water may be attributed. On the reefs, when the breakers were running at about a normal condition for half tide, the water often contained as many as 15 c.c. of oxygen to the liter, although oxygen saturation for sea-water of the same temperature and salinity was never more than 5.5 c.c. per liter.

The Growth-rate of Samoan Coral Reefs, by Alfred G. Mayor.

In April 1917 reef corals from Pago Pago Harbor, American Samoa, were measured, photographed, weighed, marked by numbered brass tags, and replaced in favorable situations upon the reef-flats either by tying them with wire to iron stakes or embedding their bases in concrete. In July 1918, these corals were again studied in order to ascertain their growth-rate, and as the specimens selected were of average size it was hoped that an approximate determination of the average growth-rate for each species might be determined.

It was our object to calculate the weight of stony matter which coral heads of average size add to the reef per annum. In order to do this the weight of the living coral was ascertained both in 1917 and in 1918. Then in 1918 the coral was killed and its animal substance macerated or dissolved in KOH, after which the fresh water was largely abstracted by washing the skeleton in 90 per cent ethyl alcohol; the coral was then dried in the sun and weighed. This showed that the weight of the dried stony substance in various species of reef corals is on an average about 0.8 that of the same coral head when alive. Various acroporas ranged from 0.07 to 0.9, while branched porites were about 0.8 and large massive porites slightly above 0.9.

Applying this correction, we find that on these Samoan reefs the gain per annum avoirdupois weight of stony substance in various coral heads of average size appears to be as follows: *Acropora*, 19 ounces; *Porites*, 8 ounces; *Pocillopora*, 10 ounces; *Pavona*, 12 ounces; *Psammocora*, 3 ounces. Knowing the number of coral heads of these genera upon a reef-flat, we have a means for ascertaining the weight of limestone added to the reef each year by the growth of coral upon its upper surface.

By counting the numbers of coral heads and species of corals on squares of 24 feet on the side (576 square feet), the squares being staked out from 50 to 100 feet apart from the shore to the seaward edge of the reef-flat, we are led to the following conclusions:

On the upper surface of the Aua reef-flat between Breaker Point, Pago Pago Harbor, and the southern end of Aua village, the area of the reef being 2,550,000 square feet, the numbers of corals are approximately as follows:

- About 502,200 heads of *Porites* grow over 72 per cent of the area of the upper surface of the reef-flat and contribute (due to their growth) per annum 251,000 pounds of limestone.
- 347,500 *Acropora* distributed over 56 per cent of the reef-flat contribute annually 500,400 pounds of limestone.
- 57,600 heads of *Pocillopora* scattered over the entire reef-flat contribute 31,700 pounds of limestone.
- 55,900 *Psammocora* distributed over 30 per cent of the reef-flat contribute each year 11,000 pounds of limestone.
- 15,500 *Pavona* found over 35 per cent of the reef-flat area contribute each year about 11,600 pounds of limestone.

Thus the growth of these corals appears to add about 805,000 pounds of limestone each year to the upper surface of the reef-flat, and as these genera contribute 95 per cent of the entire coral heads of the reef-flat, it is probable that about 847,000 pounds of limestone are added to the coral reef each year by the growth of the corals over its surface.

There are, however, certain obvious losses which may be approximately determined. Among these the wash of the breakers due to the prevailing trade-wind drives a current of about 40 feet per minute over the surface of the reef-flat from Breaker Point northward to the jagged northern edge of the reef-flat, over which the drifted limestone sand spills into deep water.

In order to determine the annual loss of loose limestone sand lost to the reef-flat by being drifted off its northern edge, 6 barrels (each 2 feet in diameter) were weighted with volcanic rocks and sunk off the reef-flat close to the northern edge, so that the water was about 1 foot over their open tops at lowest tide. It was found that on an average each barrel caught 0.7 pound of limestone sand per day, the sand being dehydrated in alcohol and dried in the sun before being weighed. Further tests showed that the barrels caught on an average only 12 per cent of the sand which was carried in the current over their open tops from the edge of the reef-flat.

The northern edge of the reef-flat is about 1,200 feet wide, but sand spills over its edge along only about 800 feet of this length, the 400 outermost feet of reef edge being subjected to the constant inward wash of the waves. Using these data, it appears that about 100,000 pounds of sand are washed off from the reef-flat by currents each year.

There are 290,000 holothurians on the Aua reef-flat between Breaker Point and the edge of the reef off Aua Village, and as the acidity of their gastric cavities appears to be the same as that of the holothurians of Florida, each one (according to experiments made at Tortugas in 1917) might be expected to dissolve 10 pounds of sand per annum, or 2,900,000 pounds of sand may be destroyed annually over this reef-flat by solution due to holothurians.

Thus the corals appear to add annually about 840,000 pounds of limestone to the reef, but 3,000,000 pounds, or nearly 4 times this weight of limestone, appears to be removed annually by holothurians and by currents. Other factors, such as boring algæ, mollusca, and fishes (the efficacy of which we have not been able to calculate), add still more to the destruction of limestone, although their influence is in some measure offset by the growth of nullipore algæ and lithothamnion. Alcyonaria, although a decided factor in some reefs, are so rare as to be negligible over the Aua reef-flat.

In most respects this Aua reef is a typical average Pacific fringing-reef, and our data appear to explain the disappearance of the lithothamnion ridge over the shoreward parts of the reef-flat as the reef grows outward. Moreover, the reef-flat appears to be deepening at present, although the average depth of water over it at low spring tide is less than 12 inches. This does not mean

that such a fringing-reef must necessarily change into a barrier reef through waste and solution of limestone from its floor, for as the reef-flat deepens the currents must lessen, and a uniformly sandy or muddy bottom is not so favorable for holothurians as are the small patches of limestone sand largely surrounded by dead and broken coral, such as characterize the Aua reef-flat to-day. Thus as the reef-flat deepens the factors which destroy it probably diminish and a balance may be attained between the accession of limestone due to growth of corals and other organisms and its loss due to mechanical and organic causes.

It is interesting to see that although *Porites* heads are more numerous than *Acropora*, yet *Acropora* (due to its remarkable growth-rate) is the most important coral genus in building up the Pacific reefs.

We find that the Samoan corals grow fully twice as fast as do those of Florida and the Bahamas according to Vaughan. As I have stated elsewhere in this report, this is probably due to the better food-supply in the Pacific.

Our results explain the disappearance of the lithothamnion ridge over the shoreward parts of the reef-flat.

*Alkalinity of Surface Waters of the Atlantic and Pacific Oceans, by
Alfred G. Mayor.*

The alkalinity of the surface-water of the Atlantic was tested each day at noon upon voyages from New York to Key West and returning in February 1918, and also in going from New York to Trinidad, British West Indies, in March and returning in May 1918. The results show that the cold, dull-colored water which drifts down the Atlantic coast of America from the Gulf of St. Lawrence to Cape Canaveral, Florida, is less alkaline than the warm deep-blue water of the so-called Gulf Stream. Thus the alkalinity of the Gulf Stream, tropical Atlantic, and Caribbean Sea ranges from 8.2 to 8.25 PH, being usually about 8.22, while that of the shore current along the coast from New York to middle Florida is about 8.1 PH, ranging from 8 to 8.17.

Moreover, the shore current is relatively dilute, its salinity ranging from 30.77 to 35.71 grams per 1,000 grams of water, being more brackish close to shore than it is along its outer edge near the Gulf Stream. In the Gulf Stream and tropical Atlantic north of the Caribbean Sea the salinity is well above 36 grams of salts per 1,000 grams of water, while in the Caribbean it is slightly lower, ranging in our tests from 35.28 north of Grenada to 36.08 near Saba. This lowered salinity may be due to the effect of the great rivers of South America, for the muddy surface current at Mayaro Bay, off the east coast of Trinidad, British West Indies, had a PH of 8.17 at 26.1° C., and its salinity was only 31.85 on March 20, 1918.

Upon leaving the Gulf Stream and entering the shore current off the Atlantic coast of the United States, the alkalinity of the water suddenly changes from about 8.2 to 8.1 PH or lower, and this easily effected test might serve to inform ship captains of the fact that they had entered the region of the coastal drift.

Studies in the Pacific were made upon a voyage from San Francisco, California, to Honolulu, and thence to Samoa, and returning in 1917; and also in June 1918, when we steamed from San Francisco to Honolulu and thence to Pago Pago, Samoa. We also went from Samoa to Fiji in August, and from the Fiji Islands to Vancouver, British Columbia, in September 1918. It appears that the cold current which sets southward along the Pacific coast of the United States is relatively acid and of 8.05 PH about 100 miles from shore and 8.17 PH about 1,000 miles out between the American coast and the Hawaiian Islands. Beyond this, in the tropical regions of the mid-Pacific, the water of the prevailing westerly drift is more alkaline, ranging from 8.2 to 8.25 PH.

It was remarkable, however, that in the tropical Pacific, whenever we met with a decided counter current running in an easterly direction against the prevailing westerly drift, the water became relatively acid, ranging from 8.1 to 8.18 PH. This easterly counter current is often encountered in the mid-Pacific about 5° north of the equator, in the region of such low-lying coral islets as Palmyra, and the Phoenix or Union Groups, and is a menace to vessels because of the absence of lighthouses, the uncertainty of the presence or absence of the current, and the difficulty in seeing submerged reefs and small low islands at night.

The ease and rapidity with which anyone can test the alkalinity of sea-water, using some such indicator as thymolsulphonephthalein, may enable this method to become of aid to navigation in these dangerous waters. One has only to mix the water with a few drops of the dye, and if the mixture is greenish-blue it is alkaline, while an approach toward acidity produces a more nearly yellow color. This method may also be used wherever the ship passes out of a current of tropical origin, which, being warm, is alkaline, into another current of colder water, which, due to its low temperature, is relatively less alkaline than the sea-water of the tropics.

The presence of CO₂ causes the sea-water to become relatively acid, and it is possible that in the mid-Pacific the easterly counter current of relatively acid water may be derived from cold, deep water which, upon rising to the surface, becomes warmed to a temperature practically identical with that of the surrounding westerly set, but still retains some of the CO₂ characteristic of the waters of the deep sea. Indeed, one would expect that the general westerly trend of the surface-waters along the wide equatorial belt of the mid-Pacific may set up a counter current in the underlying depths tending to counterbalance the surface drift. Occasionally this deep-lying counter current may appear upon the surface, in which case it still retains some of its easterly movement and some of its excess of CO₂.

Report of Work done upon Annelids in 1918, by A. L. Treadwell.

My work for this season was a continuation of that of previous years, the preparation of a monograph of the Leodiciadæ of the West Indian region. Having made an exhaustive study of the Tortugas and of the northern limit of this West Indian region at Bermuda, the research for 1918 was conducted at its southern limit in Tobago. Most of the collections were made off Pigeon Point, on Buccoo Reef, and in Buccoo Bay. Petit Trou Lagoon yielded the same mud-living forms that were found in Buccoo Bay, and one new species of *Marphysa* was found only on the sandy beach about a mile west of Scarborough. No Leodiciadæ could be found at Man O'War Bay, the only annelids obtained there being a species of a Spionid.

A considerable number of the Leodiciadæ occur throughout the West Indian region, the most constant being *Nicidion kinbergii* Webster, which has appeared in all of my collections and is always abundant in the outer layers of the decomposed coral rock. It is noteworthy that the relative abundance of most of the other species varies in different localities. Thus in Bermuda the commonest form is *Leodice mutilata*, in the Tortugas it is *Leodice fucata*, while in Tobago the large *Leodice caribæa* was common. *L. fucata*, the "palolo," has not been described from Bermuda and was rare in Tobago. Evidently its range is in the middle of the West Indian region. No observations were obtained on the question of its swarming. It was hoped to study this phenomenon in the Bahamas, but war conditions made it impossible to visit that region this year.

In all, 10 new species were collected and described, distributed as follows: *Leodice*, 2 species; *Lumbrinereis*, 3 species; *Drilonereis*, 3 species; *Arabella*, 1 species; *Marphysa*, 1 species. Colored drawings of all but two of these were obtained, and detailed descriptions will appear later.

In the preparation of the water-color drawings I had the efficient assistance of Mr. Duncan Gay.

Due to the temporary closing of the Tortugas Laboratory and the difficulties and expense of travel, but few investigators have prosecuted their studies during the past year. Moreover, war duties (such as those of the Director in teaching navigation to enlisted men in the U. S. Navy) have interfered more or less with the normal activities of the Department. Nevertheless, the work actually accomplished has been performed under the best conditions, and among other results we now have the only satisfactory data upon the growth of Pacific corals, and charts might well state that an average growth of 1 inch per annum may be expected in channels through coral reefs.

Moreover, in the Pacific, it appears that surface currents moving toward the east in opposition to the prevailing westerly drift are relatively acid, as are also currents of arctic or subarctic origin which flow into warmer regions. This leads one to suspect that counter currents which set toward the east consist of deep water coming to the surface; and the ease and rapidity with which one can determine the alkalinity may enable us to provide ship captains with a means for detecting the presence of a back-set current before the ship has been deflected from her intended course.

We believe also that we can now devise apparatus for drilling rapidly through coral reefs and bringing up a continuous core.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

BENJAMIN BOSS, DIRECTOR.

While considerable work remains to be accomplished before the General Catalogue is completed, it is inadvisable to carry it too near the final stages before considering the steps to be taken in the future, lest the machinery of the Department suffer through lost motion, with consequent economic loss.

In order to direct our efforts where they may accomplish the maximum of benefit to the astronomy of position, a careful survey must be made of past investigations in their bearing upon future needs. We should construe these needs in a liberal sense. For, however praiseworthy it may be for the investigator to open up new fields through his individual efforts, it is far better for his science if, in addition, he so directs his efforts as to provide for the needs of coming generations. A concrete case in illustration of this point is furnished by the past history of star catalogues. The great majority have been formed without any fixed plan or purpose, whereas had they been designed to cover a particular field their usefulness to modern astronomy of position would have been doubled, with no additional expenditure of energy.

It is also natural and imperative that most careful thought should be exercised to insure the employment of the most economical means in the accomplishment of any undertaking.

The recent successful applications of photography to the field of the astronomy of position have so materially reduced the cost of producing a star position that it becomes imperative for any observatory employed in astrometrical work to adopt photographic methods as far as practicable. This does not in any sense involve a change in the fundamentals of the science. The change is merely one in technic. It is clear, therefore, that the Department of Meridian Astrometry must adopt photographic methods in any future undertaking.

Careful consideration has been given to the problem of the future needs in the field of the astronomy of position for the purpose of selecting a program for the Department. Following our established lines of research, we will naturally determine star positions. But it must be understood that a star position in itself is at best of very temporary value, and, considered alone, can be applied only to some immediate problem. It is only when the star position is designed to serve some ulterior purpose that it deserves consideration. In the past our object in determining star positions has been to derive their proper-motions with a view to the study of systematic motion; so it would seem but natural that we should continue these studies, utilizing our past experience in mapping out our future program.

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Judging from the rapid developments of the last decade, it is extremely risky to predict the exact needs of the future, and therefore it seems advisable to plan a program which will be at the same time comprehensive and feasible. The General Catalogue will furnish proper-motions of stars to the seventh magnitude. It is eminently desirable to provide for proper-motions of fainter stars; the larger the range of magnitude the more comprehensive the study of stellar motions. As each step toward fainter magnitudes immensely increases the number of stars involved, it is out of the question to determine the proper-motions of all the stars of any particular magnitude unless we limit the study to the brighter stars. It is therefore proposed to form a selected list of stars from each magnitude and to extend the range of magnitude as far as possible, the size of the list being regulated partly by present requirements and partly by our ability to handle it. Thus the program is flexible and can be adjusted to meet the actual conditions encountered.

The method of attack is dictated by past experience. Since no means have been devised whereby absolute positions of stars can be determined photographically, it becomes necessary to base the photographic measures upon meridian observations. For this purpose it is proposed to observe a list of comparison stars, approximately one to each square degree, with a meridian-circle instrument, the meridian observations to be taken simultaneously with the photographic program. It is further intended to observe in broad zones, which facilitates the formation of a homogeneous system. Two photographic telescopes will be required to cover the range in magnitudes desired. They should be designed to photograph a large field. It is proposed to cover the entire sky for the brighter stars, and for fainter stars many selected areas will be taken, with special attention devoted to the Galaxy.

While the positions of only a portion of the stars will be measured, there will be a permanent record of the sky as it appears to-day available at any time for anyone interested in a particular region or in some new problem requiring additional stars. A repetition of this program at intervals in the future will lay the foundations for an exhaustive study of the motions of the stars.

INVESTIGATIONS IN PROGRESS.

STELLAR PARALLAXES.

In order to pursue the study of the real motions of the stars in space it becomes necessary to systematize, as far as possible, the results of the various stellar-parallax observers, since in many cases a number of determinations have been made of the parallax of an individual star.

An important question which must be disposed of first of all is that of the parallax of the comparison stars used by the observer. For

lack of a better method, the mean parallax of stars of any particular class is used. Various tables have been constructed for this purpose. In general the mean parallaxes have seemed too large, so an attempt has been made to prepare new values. The new tables are based upon magnitude effects and the effect of galactic latitude upon mean parallax. Account should be taken of the type of the comparison stars, but in the present investigation this has been omitted mainly because the types of the comparison stars are in many cases unknown.

As Adams parallaxes are so numerous they are apt to exert a preponderating influence upon the system, and consequently it seemed advisable to test their systematic accuracy. Residuals were formed, Adams minus author, which yield both the constant difference between Adams and the author and the probable error of a parallax determined by the author. These results were compared with a more independent method of obtaining the same quantities. Where three or more authorities have furnished parallaxes for any particular star their results have been combined according to an arbitrary system of weights depending in part upon the probable errors. Comparisons of the results obtained in this way with the results derived from a comparison with Adams show a remarkable agreement and thus serve as proof of the systematic excellence of Adams results.

A second approximation to a system was therefore attempted for which all stars were used where two or more values of the parallax are given. These results were treated not only for constant systematic corrections, but also for a term dependent upon sine and cosine of the right-ascension, and sine and cosine of double the right-ascension. The expressions for systematic parallax obtained in this way fit the observed results remarkably well in most cases. A digression from this rule was made in the case of the first set of parallaxes published by Flint. It was found that after the rejection of abnormally discordant parallaxes the remainder are excellently represented by a term depending upon the sine and cosine of triple the right-ascension. As the second approximation fits the observed results most satisfactorily, another approximation was deemed unnecessary.

A system of weights was formed dependent upon a comparison between the computed and observed weights of the parallaxes. Since the formation of this system the Director has been generously offered the unpublished results of a large number of parallaxes, which will be used to revise the system before publication.

Two features of the investigation were quite unexpected. First, the probable error of Adams parallaxes should theoretically approach zero with decrease in the parallaxes toward zero, whereas the actual probable error seems to be constant for parallaxes under $0''.1$, with a considerable increase past this limit. Secondly, the gain in accuracy for any particular parallax through the employment of more than one plate in its determination is scarcely appreciable.

While there is considerable variation between the observed and real probable errors of the different authorities, it may be said that the observed probable errors represent the true probable errors fairly accurately in a systematic sense.

STELLAR LUMINOSITIES AND ABSOLUTE MAGNITUDES.

Employing the systematic corrections to parallax previously alluded to, the absolute luminosities and magnitudes of a large number of stars were derived. Generally speaking, the results of Russell were confirmed. For the stars of type K and M the division into "giant" and "dwarf" stars is very marked, while the stars of types A and B are practically wholly confined to the "giant" class. For F and G type stars, however, there appears to be a considerable proportion of stars intermediate between the two classes. Accidental errors in the determination of magnitude or type could easily account for some of the intermediate stars. There may also be a physical explanation. If we admit the possibility of Russell's suggested development of a star from M "giant" through intermediate types to M "dwarf," it is very probable that many stars never develop beyond the F or G type, and this would account for the intermediate class of absolute magnitudes among the F and G type stars.

The absolute magnitudes of the "dwarf" stars present an almost arithmetical progression from F to K type, but the M-type stars are a full magnitude fainter than an arithmetical progression would indicate. The range of absolute magnitude for the "giant" stars is considerable. Taking means by type there is an increase in magnitude from "giant" M-type to "giant" G and then a decrease.

REAL STELLAR MOTIONS.

The first attempt of the Director to discuss the real motions of the stars was based upon fairly uniform material in a systematic sense. The parallaxes, published by Adams and Joy, and the proper-motions of the Preliminary General Catalogue were used exclusively. Radial velocities were taken from the results published by the Lick and Mount Wilson observatories. From this data the apices of the real motion of each star were computed, together with the velocity in space. The total number of stars discussed was 219. In spite of the small number, several striking phenomena were quite definitely shown.

1. There is a Solar Group, so termed because it is moving approximately in the direction of solar motion at a rate of about 22 kilometers per second. The true coordinates of this motion are $A = 270^\circ$, $D = +16^\circ$. The group is mainly composed of "giant" stars.

2. The solar motion determined from "dwarf" stars is in sufficient agreement with that determined from "giant" stars to suggest the conclusion that they belong to the same system.

3. Combining all the material, the apex of solar motion is placed at $A=270^\circ$, $D=+30^\circ$, and its resultant velocity is nearly 24 kilometers.

4. There is a distinct difference between the velocity figures of "dwarf" and "giant" stars both as to variation and the relative length of the axes. The velocity figure of the "dwarf" stars is fairly representative of preferential motion as previously determined; that of the "giant" stars is a clover-leaf figure produced by the Solar Group, one wing of the "dwarf" figure, and a group of high-velocity stars whose motions are directed along the galactic equator from 180° to 360° galactic longitude.

5. The orientation of the velocity figure is independent of spectral type but dependent upon "giant" and "dwarf" classification. The axes of the velocity figure are dependent upon both type and "giant" and "dwarf" classification.

A further study of the real motions of the stars is partly completed, based upon all available material. The sources of radial velocities and proper-motions are mainly those which formed the basis of the first study. The parallaxes were derived by application of the corrections resulting from the investigation of systematic error of parallaxes already alluded to. In general, the conclusions arrived at in the first discussion of real stellar motions were verified. In addition there appears to be a tendency of motion on the part of a small group toward the region 0^h to 2^h of right-ascension and 0° to $+20^\circ$ of declination. Another feature of interest is the distribution of apices according to velocity. The apices of stars whose true space velocity is over 75 kilometers per second lie almost wholly along the Galaxy. They are definitely confined within the region 140° to 340° galactic longitude, and contain a mixture of "dwarf" and "giant" stars. There are no apices for stars of large velocity between longitudes 340° and 140° . On the other hand, the distribution of the apices of stars of small velocity (less than 15 kilometers per second) is quite irregular. Several more or less definite features appear, however. In the first place, the conditions of distribution of the apices of high-velocity stars along the Galaxy are practically reversed; secondly, the grouping of apices in the region 0^h to 3^h right-ascension and 0° to $+20^\circ$ of declination is marked; and thirdly, there is an indication of the secondary plane of distribution mentioned in Year Book No. 16, 1917.

The distribution of the apices of the A and B type stars is quite irregular from 0^h to 12^h of right-ascension. Beyond that meridian there is a fairly compact clustering of apices in the neighborhood of the Solar Group. One dense cluster of seven A-type stars lying between 285° and 295° of right-ascension and 0° and -10° of declination has the appearance of a star-stream. The mean space velocity of the stream is 30 kilometers per second and the extreme deviation from

this mean is 6 kilometers. The deviation of the individual values of space velocity from the mean is no larger than in the case of the members of the Taurus group. The seven members of the group are widely scattered over the sky.

Another significant feature of the investigation results from a discussion of the space velocity arranged according to type. Starting with a mean velocity of about 40 kilometers for M and K type "giants," the velocity by type decreases to about 15 kilometers for stars of type B and then rapidly increases for "dwarf" stars, apparently reaching a maximum about the G-type. The phenomenon is easily explainable on the assumption that only the stars of greatest mass reach the B-type development.

While the investigation is in shape for printing, the publication will be delayed awaiting the revision of the system of parallaxes through the acquisition of additional data which has been generously offered by Professors Schlesinger, Mitchell, Miller, Campbell, and Frost. Professor Pickering has made it possible to revise the study of the absolute magnitudes by supplying the spectral types as determined for the new Draper Catalogue.

PERSONALITY IN THE ESTIMATION OF TENTHS.

In estimating the position of an index between two scale-rulings to tenths of the scale interval personality plays an important part. The list of percentages giving the frequency with which each tenth is represented in the estimations of an observer is known as the observer's personal scale. In connection with the design of measuring scales for a special measuring-instrument it seemed desirable to know the magnitude and nature of errors to be anticipated due to the personal scales of the measures. Accordingly, Dr. Albrecht has made a detailed investigation of the personal scales for sixteen present and former observers of the Dudley Observatory, extending over periods of more than twenty years for some of the observers. The principal results may be briefly summarized as follows:

(a) The personal scales for different observers may differ widely from each other.

(b) For any particular observer the personal scale is remarkably constant over short and moderately long periods of time, even up to one year.

(c) Fatigue appears not to change the personal scale appreciably. For example, it remains essentially constant during 5 hours of continuous observing at great speed.

(d) For some observers the personal scale remained practically unchanged for 8 or 10 years, the entire period covered by the data, while for other observers it was found to undergo a gradual and more or less progressive change from year to year.

Tests were also made on specially ruled scales in order to determine the extent to which different widths of the scale-rulings and of the

index influence the estimated position of the index. The indications are that this influence, which is superimposed upon the personal tendency referred to above, is different for different observers, being very slight for some and more appreciable for other observers. One of the principal effects produced by a large increase in the widths of the lines is to render the estimations more difficult and troublesome. Most observers find it much easier to make the estimations with moderately narrow lines—widths of the order of one-twentieth of the scale interval—than with wide lines. This fact is also brought out by the larger range in the differences “estimated minus measured” and by the increase in the probable error of a single estimation.

The investigation is being somewhat extended, especially with the view to learning to what extent observers without any previous experience in estimating tenths may acquire and hold a correct personal scale.

OBSERVATIONS.

During the year 2,769 observations were taken on 34 nights, with 182 supplementary observations on 15 dates for clock, etc. The observations were distributed among the observers as follows: S. Albrecht, 1,263; Arthur J. Roy, 684; W. B. Varnum, 822. The circle readings for zenith distance showed the following distribution: S. B. Grant, 704; H. Jenkins, 1,225; H. Raymond, 684; C. L. Stearns, 76. In respect to the positions of the instrument these observations were distributed: AE 1,343, AW 1,426. So few stars have less than the full quota of observations that the program can now be considered finished.

REDUCTION.

All classes of reductions as enumerated in previous reports have been brought so nearly up to date that some preliminary results on the fundamental stars are being collected.

The collection of the San Luis observations of the three fundamental observers has been completed and a further investigation for personal

Differences in declination between observers.

	R-V	V-T	T-R		R-V	V-T	T-R
+47°	-0°34	+0°32	-0°09	-34°	-0°01	-0°09	+0°05
+42	+0.01	+0.23	-0.07	-38	+0.02	-0.11	+0.09
+37	-0.40	+0.30	+0.09	-42	-0.01	-0.09	+0.12
+32	+0.14	+0.09	-0.06	-47	+0.05	-0.10	+0.04
+27	-0.06	+0.02	+0.06	-52	+0.13	-0.06	-0.01
+22	-0.07	0.00	+0.09	-57	+0.06	-0.07	+0.03
+17	+0.07	0.00	-0.08	-62	+0.06	-0.02	+0.02
+12	-0.03	+0.05	-0.01	-67	+0.02	-0.01	-0.02
+ 7	+0.06	-0.01	-0.02	-72	+0.05	+0.02	-0.06
+ 2	+0.09	+0.05	-0.14	-77	+0.05	+0.01	-0.03
- 2	+0.05	-0.03	+0.02	-82	-0.02	+0.10	-0.06
- 7	+0.04	+0.01	-0.02	-87	-0.03	+0.01	0.00
-12	+0.17	-0.12	-0.05	-93	-0.07	+0.18	-0.14
-17	+0.03	+0.02	-0.03	-98	-0.35	+0.39	+0.08
-22	+0.05	-0.06	0.00	-103	-0.28	+0.32	-0.03
-27	+0.02	+0.02	-0.02	-108	+0.08	-0.07	-0.06
-31	+0.01	0.00	-0.02	-113	-0.21	-0.24	+0.52

differences is being made. The first results are exhibited in the following table, the divisions between groups being generally at the 5° points. The slight divergence across the zenith precludes any material error in the applied correction for North minus South.

The corrections for the effect South minus North and eye and ear minus chronograph are as follows for the different observers.

	S-N	E and E-Chron.
S. Albrecht.....	-0°008	-0°0141 sec. δ
B. Boss.....	+ .023	- .0078 "
A. J. Roy.....	- .002	- .0044 "
W. B. Varnum....	+ .012	+ .0009 "

The magnitude corrections are represented by the following quantities multiplied by (M-3.5).

	S. of zenith.	N. of zenith.
S. Albrecht.....	-0°0057	-0°0167
B. Boss.....	- .0096	- .0086
A. J. Roy.....	- .0014	- .0183
W. B. Varnum....	- .0022	- .0092

STAFF.

The Director has devoted most of his time to the preliminary steps in some statistical studies, to the formation of a system of parallaxes, and to a study of the real space-motion of stars. Dr. Sebastian Albrecht has continued his investigations of standards of wave-length and has studied the problem of personalities as affecting estimations of tenths on a divided circle. Mr. Sherwood B. Grant has devoted his time to reductions of observations. Mr. Heroy Jenkins, in addition to reduction of observations, has been preparing the material for the determination of the systematic errors of recent star catalogues. Mr. Harry Raymond has rendered valuable aid in many departments of the work. Mr. Arthur J. Roy has supervised the reduction of observations and has been discussing the effects of personality on the San Luis observations. Mr. Roscoe F. Sanford was engaged upon several branches of the work. Mr. Carl L. Stearns also performed a variety of computations. Mr. William B. Varnum has brought the computations of some of the instrumental constants nearly up to date.

The computing division has been composed of Miss Grace I. Buffum, Mrs. Livia C. Clark, Miss Mabel I. Doran, Miss Mabel A. Dyer, Miss Alice M. Fuller, Mrs. Mary B. James, Miss Bertha W. Jones, Miss Isabella Lange, Miss Marie Lange, Miss Frances L. MacNeill, and Miss Helen M. MacNeill.

The following resignations have taken place during the year: Dr. Roscoe F. Sanford, December 1917; Mr. Carl L. Stearns, May 1918; Miss Mabel A. Dyer, October 1917; Miss Bertha W. Jones, March 1918.

Miss Helen M. MacNeill joined the staff February 1918, and Miss Mabel I. Doran May 1918.

MOUNT WILSON OBSERVATORY.

GEORGE E. HALE, DIRECTOR.

INTRODUCTORY SKETCH OF THE YEAR'S WORK.

In times like these, when the fundamental principles of civilization, for which the man of science must always contend, are seriously imperiled by the savage attack of the Central Powers, the duty of a research institution is plainly evident: it must utilize every available resource in aiding to overcome the enemy. For this reason the Mount Wilson Observatory, in harmony with the policy which has guided the Carnegie Institution since the entrance of the United States into the war, has endeavored to be of service to the Government. The Director's work in this field began in April 1916, when he was called upon by the National Academy of Sciences to assist in the organization of the National Research Council. Since that date his duties in connection with the Council have kept him in or near Washington during the greater part of the time. During these periods of absence Dr. Adams has conducted the Observatory as Acting Director. Most of the work described in the present report was thus done under his general direction.

Many other members of the Observatory staff have also devoted themselves to war service. In view of the confidential nature of much of the work thus undertaken, the various war activities of the Observatory have been made the subject of a separate report to the President of the Carnegie Institution. It may be stated, however, that most of the facilities of the instrument and optical shops, and many of those of the physical laboratory, have been utilized for Government purposes. A specially equipped laboratory has also been built (in cooperation with Throop College of Technology) for experimental researches for the Navy, and a large optical shop, in which one hundred opticians will be trained for work of precision, has been erected at the request of the Ordnance Department of the Army. Those members of the staff who have not yet been called into war service have continued their investigations with great vigor and success.

Many of the efforts initially directed to war service may also contribute in a permanent way to the promotion of research. Thus the organization and development of the National Research Council have been effected with both of these objects in view. The losses which science has sustained because of the war must be made good, and advantage should therefore be taken of the present unique opportunity to demonstrate the national importance of research and the advantages to be derived from cooperation among investigators. The policy of the National Research Council is based upon this principle. In the organization of the Research Information Service, for example,

which has involved the establishment by the State Department of the new position of scientific attaché in our embassies at London, Paris, and Rome, the needs of war are the first but not the sole consideration. The step thus taken toward more effective international cooperation in research should be quite as useful to the future of science as in the present prosecution of the war. In this country the close cooperation between governmental, educational, and industrial research agencies, recently effected for the solution of war problems, should not altogether cease after the conclusion of peace. In short, the stimulus derived from a great national awakening, and the momentum acquired under the pressure of war conditions, should be conserved as a means of offsetting the serious losses, both of men and of revenue, which the war is sure to entail. An expression of the broader purpose of the National Research Council may be found in the Executive Order providing for its perpetuation, which was issued by President Wilson on May 11 of the present year.

One of the endeavors of this Observatory since its inception has been to develop instrumental methods permitting the daily observation of phenomena previously recorded only at total eclipses of the sun. The forms of the prominences can now be studied more effectively in full sunlight than at eclipses, because they can be repeatedly photographed in plan on the sun's surface as well as in elevation at the limb. The spectrum of the lower chromosphere can also be dealt with more successfully in sunlight, at least so far as the precise determination of the positions of the lines is concerned. But to record the faintest lines of the flash spectrum, and its changes in character at different levels, we must still have recourse to eclipses. As for the corona, all attempts to observe it in full sunlight have hitherto met with no success.

For such reasons, the Assistant Director organized a well-equipped expedition to observe the total eclipse of June 8 at Green River, Wyoming. In spite of clouds, which wholly prevented visual observations of the corona, some valuable results were obtained. These include sharply defined photographs of the prominences and of certain portions of the inner corona, and an admirable long-exposure photograph of the corona, showing no trace of interference by clouds. The wave-length of the coronal line at one limb of the sun was photographically determined with high precision, and the brighter lines of the flash spectrum, as well as the corona in ultra-violet light, were also successfully photographed.

The sun-spot maximum has certainly been passed, yet the magnetic polarities of the spots continue to follow the rule that has governed them since the minimum. Exceptions to this rule are very few in number (about 3 per cent), but the direction of whirl in the secondary vortices photographed in the hydrogen atmosphere above sun-spots

does not appear to be so consistently defined. However, the disturbing conditions existing in complex spot-groups, together with other causes, frequently prevent the certain determination of the direction of the whirl in the H α flocculi.

Our first investigation of the general magnetic field of the sun has been essentially completed. The results include the discovery of the existence of the field, the detection of thirty lines showing magnetic displacements, the determination of the sun's magnetic polarity, and the measurement of the strength of the field at different levels in the solar atmosphere, the inclination of the sun's magnetic axis, and the period of its revolution about the solar axis of rotation. Certain anomalies encountered in this research remain to be studied, but it will be impossible to gather observational material for further investigation of the general magnetic field before the approach of the sun-spot minimum, because of the disturbing effect of the powerful magnetic fields in sun-spots.

The spectrographic measurement of the solar rotation has led in recent years to curiously discordant views among the various astronomers who have undertaken it. At Mount Wilson the variations in rotational velocity observed over the period 1914 to 1918 show no evidence of periodicity, but seem to depend upon just such temporary conditions in the sun's atmosphere as our knowledge of solar phenomena would lead us to expect. An important confirmation of previous conclusions has resulted from a comparison of the rotational velocities given on the same photographs by the high-level H and K lines of calcium and the low-level lines of the cyanogen band. The velocities for calcium are from 10 to 15 per cent greater than for the cyanogen below, and these differences increase for higher latitudes.

The determination of stellar parallaxes has been pushed forward with the 60-inch reflector, using both the trigonometric and spectroscopic methods. By the former means 26 new parallaxes have been determined, for the most part of stars of small proper motion and advanced spectral type. The list also includes Nova Persei No. 2, Barnard's star of great proper motion, and three nebulae. The absolute magnitudes of the central star of three planetary nebulae determined here are +6.1, +8.1, and +9.4, giving a mean value of +7.9. It is interesting to note, though it may be merely a coincidence, that this value is in close agreement with the absolute magnitude +6.9 found for the three novae, at minimum brightness, of which the parallax is known.

The spectroscopic method of parallax determination, which yields results of high precision at minimum cost of time, has been effectively utilized for the measurement of the absolute magnitudes of several hundred stars during the year. Peculiarities detected in the spectra of the Cepheid variables, including exceptional intensity of the hydro-

gen and the enhanced lines, have necessitated changes in reduction methods, which have led to values of their absolute magnitudes somewhat brighter than those obtained before these peculiarities were discovered.

Professor Kapteyn has continued his researches on the parallaxes and motions of the brighter galactic helium stars and has added individual parallaxes and motions for practically all the known helium stars within galactic longitudes 150° and 216° and latitudes $+30^\circ$ and -30° . The proper motions of these stars are very small; but, through the fortunate circumstance that their peculiar motions are also exceptionally small, a solution of the problem has been possible. Most of the helium stars in the vicinity of the Orion nebula appear to form a local group whose parallax is $0''.0054$. Those outside this group are somewhat less distant, their mean parallax being $0''.0081$. The investigation affords a valuable mass of material for the study of luminosity curves, which can now be extended to stars of fainter intrinsic luminosity than has hitherto been possible.

The rapid accumulation of data on radial velocities and absolute magnitudes has made possible a new determination of the solar and stream motions. The discussion of the stream-motion is based upon stars of types F, G, and K, separated into three groups according to distance. The average radial velocity for different directions leads to a mean velocity surface which reveals at once the direction of greatest radial mobility. The vertices thus found agree closely with those derived from proper motions. Certain peculiarities in the form of the surface suggest that the stars studied are mainly moving around the center of the galactic system with a preferential motion in the galactic plane.

Attention has previously been called to the peculiar behavior of the lines of calcium in the spectroscopic binary Boss 46, which yield radial velocities differing widely from those derived from other lines in the spectrum. A continuation of the observations has shown that the velocities from both sources are variable and have the same period. The range for the lines of hydrogen and helium is exceptionally large, amounting to nearly 450 km., while that for the calcium lines is about 20 km. The difficulties of interpretation are increased by the fact that the motion of the system as derived from the two sets of lines differs by about 20 km.

The early detection of Nova Aquilæ No. 3 at Mount Wilson on June 8 was fortunate, as it permitted an extensive series of spectroscopic observations to be begun at an early stage in the star's outburst. Of the many interesting phenomena since recorded in the rapidly changing spectrum of this object, the appearance of numerous narrow enhanced absorption lines on June 10, persisting until June 15, is perhaps the most remarkable. Although the radial velocity of

the star, as measured with the aid of other lines, appears to be only about -15 km., the enhanced lines on June 10 showed displacements, proportional to the wave-length, which should apparently be ascribed to a velocity of the corresponding gases amounting to $-1,460$ km. These displacements increased daily, until on June 15 they corresponded to a velocity of $-1,630$ km. The explanation of this apparent velocity, uniformly accelerating for several days, of the vapors of iron, titanium, chromium, strontium, and other elements in the atmosphere of the star can not yet be given, but it must have an important bearing upon the theory of temporary stars. It recalls the expanding nebula about Nova Persei, but in the present case no such nebula has been detected.

The completion of the determination of the photographic magnitudes of stars in 115 of the Selected Areas of Kapteyn, and the advanced stage of the task of completing these magnitudes for 24 additional areas, brings this extensive research to a point where publication of the details will soon be feasible. An intercomparison of the areas of each zone shows a very satisfactory accordance of the results, leaving no doubt as to the high precision of the measures. Nearly half the photographs required for the determination of photovisual magnitudes in the Selected Areas have also been secured.

The photographic method of determining the colors of stars, described in the annual report for 1916, has been utilized in a study of the dependence of color upon absolute magnitude in stars of the same spectral type. In the case of red stars the effect is very considerable, giants and dwarfs indicating a difference amounting to about half a magnitude in the color index. Further use of this method, especially in conjunction with spectroscopic observations, promises to yield results of interest.

The continuation of a comprehensive investigation of globular star-clusters has resulted in an important addition, comprising novel and radical features, to existing theories of cosmogony. The absolute distances of all known globular clusters have been derived, directly or indirectly, from a remarkable relation which gives the absolute magnitude of a typical Cepheid variable star when its period of light variation is known. The clusters are thus found to range in distance from 6,500 to nearly 70,000 parsecs, and to be secondary organizations in comparison with the Galaxy, which appears vastly greater in extent than hitherto supposed. Less-complete evidence also supports the view that the spiral nebulae, instead of being "island universes," are part and parcel of a single, all-embracing sidereal system. The average brightness of the faint temporary stars discovered in spiral nebulae, of which 14 have now been found, may serve as a valuable means of measuring the distances and dimensions of these objects. The general investigation also indicates that a large, open, flattened

star-cluster exists in the neighborhood of the sun, with its center some 50 parsecs to the north of the central plane of the Galaxy. This immediately suggests the hypothesis that the phenomena of star streaming results in part from the apparent motion of this cluster through a general field of stars widely scattered through space.

The absorption of our physicists in war problems has greatly reduced the year's output of the laboratory. Some instrumental improvements have been effected, however, and investigations with the electric furnace have been extended to new regions in the spectra of manganese, iron, and titanium. The study of luminescence spectra, produced by bombardment with cathode rays, has also gone forward satisfactorily, and now includes iron, titanium, manganese, cadmium, and calcium.

The work of construction has naturally been greatly retarded by war demands, which have absorbed most of the time of the instrument and optical shops, and of the erecting force as well. Preliminary tests on stars of the 100-inch reflector, made in November, were very promising, but indicated the necessity of certain modifications in the secondary mirror support, which was hardly stiff enough to define the axis of the heavy Cassegrain mirror with sufficient exactness in all positions of the telescope. This work, together with other minor tasks needed to complete the dome and mounting, is not yet finished. It is hoped, however, that the telescope may soon be placed in commission, without delaying the war work with which the instrument shop is chiefly occupied.

The continually increasing importance of stellar observations in our program of research indicates that the time has certainly come to drop the designation "Solar" from the Observatory's name. While the term is still appropriate because of the fact that our entire scheme of operations is based upon intensive investigations of the sun as the only star that can be studied in detail, it is misleading in view of the practical completion of the 100-inch reflector, which will soon add greatly to the range and number of night observations. Hereafter, therefore, the designation "Mount Wilson Observatory" will be employed.

STAFF.

As already stated, the Director has devoted most of his time to the work of the National Research Council. He has also given such attention as he could to solar investigations, continued in collaboration with several members of the staff. As a part of this work he observed the total eclipse of the sun on June 8 at Green River, Wyoming, as a member of the Observatory expedition, which also included Messrs. Adams, St. John, Anderson, Babcock, and Ellerman. Dr. Walter S. Adams, Assistant Director, who has had general charge of the Observatory during the Director's absence, has carried forward his investi-

gations in stellar spectroscopy. Professor Frederick H. Seares, superintendent of the Computing Division and editor of the Observatory publications, has continued his work in connection with the reduction of solar magnetic observations and his researches in stellar photometry. Dr. Arthur S. King, superintendent of the Physical Laboratory, has divided his time between investigations for the Navy and the continuation of his work with the electric furnace. Dr. Charles E. St. John has divided his time between the spectrographic study of the solar rotation and the determination of solar and laboratory wavelengths of iron lines. Professor G. W. Ritchey has completed the optical parts of the 100-inch reflector and continued the photography of nebulae with the 60-inch. He has also undertaken extensive optical work for the Ordnance Department of the Army. Dr. J. A. Anderson has given all his time to war service, including the designing and testing of special micrometers constructed in our instrument shop for the Bureau of Standards, and experimental researches for the Navy. Mr. Harold D. Babcock, in addition to his work for the Navy with Dr. Anderson, spent a part of the year at the Washington office of the National Research Council. Mr. Ferdinand Ellerman has continued his solar observations and his work as Observatory photographer. Mr. Francis G. Pease continued his work of instrument design and his photographic work on nebulae and star-clusters until March, when he went to Washington to occupy the position of chief draftsman in the office of the National Research Council. Dr. Harlow Shapley has been engaged in investigations of star-clusters, variable stars, and researches in stellar photometry. Dr. Adriaan van Maanen has continued his measurement of spectra to fix the position of the sun's magnetic axis, and has carried forward his determinations of stellar parallaxes. Dr. Seth B. Nicholson has given most of his time to solar observations. Professor Alfred Joy, who has collaborated with Dr. Adams in stellar spectroscopic work, has also taken part in the solar observations. Dr. Gustav Strömberg has devoted most of his attention to a study of the correlation between stellar absolute magnitude and radial velocity, solar motion, and stream motion. Dr. Roscoe F. Sanford, who became a member of the staff in January, has given all his time to stellar spectroscopy. Mr. Arthur S. Dockham continued his work in connection with the solar observations until June, when he left the Observatory to join the National War Work Council of the Young Men's Christian Association in France.

Professor J. C. Kapteyn, who retains his position as Research Associate of the Carnegie Institution, has continued his investigations in Groningen.

The members of the Computing Division have assisted in the work of the various departments as follows: Miss Ware and Miss Miller have been engaged with the solar investigations carried on by Dr.

St. John. Miss Burwell, Miss Shumway, and for a part of the time, Miss Brayton, have made measures and reductions relating to stellar spectroscopy. Miss Richmond, Miss Joyner, Miss Winn, and Miss Davis, and, for a part of the year, Miss Carolyn Burns and Miss Helen Burns, have been occupied with stellar photometry. Miss Wolfe has given her time to reductions of stellar parallax and the sun's general magnetic field. She has also done miscellaneous computing and photographic work, and has assisted in the library. Miss Margherita Burns and Miss Brayton have both given part of their time to the work of the Physical Laboratory, although during recent months Miss Burns has assisted Dr. St. John, and, to some extent, Dr. Adams. Miss Connor has continued as librarian and has assisted with the editorial work.

Dr. John C. Duncan, director of the Whittin Observatory of Wellesley College, took part in photographic and stellar spectrographic work during the summer of 1918. Mrs. Harlow Shapley, who has continued her service as a volunteer assistant, has collaborated with Dr. Shapley in his various stellar investigations. Miss Edna Carter, associate professor of physics at Vassar College, has continued to serve as volunteer assistant in the Physical Laboratory, where she has devoted her time to the further study of metallic spectra produced by the cathode discharge. Mr. Hugo Benioff has served as volunteer assistant on Mount Wilson.

Mr. L. B. Aldrich had charge of the observations at the Smithsonian Astrophysical Observatory on Mount Wilson during the summer of 1918.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

The permanent instrumental equipment for solar work has been increased by the construction of a special form of stereoscope, designed for the combination of spectroheliograms of the hydrogen flocculi. Apparatus employed in an attempt to detect the corona in sunlight with photo-electric cells has been improvised, chiefly by utilizing accessories of the Koch registering microphotometer. The instruments used by the eclipse expedition were adapted from the equipment on Mount Wilson and that of the Physical Laboratory.

SOLAR PHOTOGRAPHY,

During the year ending August 31, 1918, the following solar photographs were taken with the 60-inch tower telescope by Messrs. Ellerman, Nicholson, Joy, Dockham, and Benioff: Photoheliograms of 6.5-inch image, 345 on 318 days; spectroheliograms with 5-foot spectroheliograph ($H\alpha$, entire 6.5-inch disk), 221 on 221 days; spectroheliograms with 13-foot spectroheliograph (K and $H\alpha$, 2-inch disk and prominences; $H\alpha$, portions of 6.5-inch disk, monochromatic light from continuous spectrum), 1,881.

Photographs of spectra taken with the 75-foot spectrograph of the 150-foot tower telescope include 346 exposures for solar rotation (Mr. St. John), 133 exposures for motion in sun-spots (Mr. St. John), and 50 for the investigation of magnetic fields in sun-spots (Mr. Ellerman).

SUN-SPOT POLARITIES.

Although the maximum has passed, sun-spots are still numerous, and an average of 20 magnetic polarities has been observed each day with the 75-foot spectrograph of the 150-foot tower telescope, or more than 7,000 for the year. The system of recording described in the last annual report has been used daily by Messrs. Ellerman, Nicholson, and Joy. The 304 drawings thus obtained on as many days give the approximate positions, polarities, and field-strengths of all spots large enough to be studied magnetically. Mr. Ellerman and Mr. Nicholson have determined the calibration curve of the parallel-plate micrometer, the readings of which are thus directly convertible into field-strength determinations. These are reliable when the field is sufficiently intense to produce actual separation of the components of the Zeeman triplet (λ 6173.553) employed, but for fields weaker than 1,000 gauss they are only approximate.

It may be recalled that at the last minimum of solar activity, the magnetic polarities of bipolar spots were reversed. Thus the preceding spots of northern bipolar groups, which before the minimum were of the same polarity as the north magnetic pole of the earth, have been of the opposite polarity since the minimum. The same reversal was observed for spots of the southern hemisphere, which are opposite in sign to the spots north of the equator. The interesting question thus arose whether a similar reversal would occur at or near the sun-spot maximum.

The maximum was certainly passed by 1918, and probably occurred in the latter half of 1917, but no general change of polarity has been observed. Both unipolar and bipolar spots frequently have small companions opposite in polarity to the principal member of the group with which they are associated, and there are also occasional groups where polarities are at variance with the general rule. Exceptions of the latter class, however, do not exceed 3 or 4 per cent of the whole, and their number has not materially increased since the maximum. It should be added that when unipolar spots are not found to correspond in polarity with preceding spots of normal bipolar groups, their history usually shows them to be the following spots of bipolar groups, in which the preceding member is temporarily absent or indicated only by the configuration of the hydrogen flocculi.

The accompanying table, prepared by Mr. Nicholson, indicates the extent to which polarities of spot-groups and the apparent direction of the whirl shown by the overlying H α flocculi correspond with the

rule given in preceding reports. The data include all spots whose polarities were observed during the calendar year 1917. It should be noted that much uncertainty attaches to the determination of the direction of the whirl on $H\alpha$ spectroheliograms, especially in members of bipolar groups. The polarities, on the contrary, can almost invariably be depended upon, although in the case of very small spots the estimates are sometimes uncertain on account of the minute displacements.

Hemisphere.	Direction of $H\alpha$ whirl.				Polarity.		
	Regu- lar.	Irreg- ular.	None.	Undeter- mined.	Regu- lar.	Irreg- ular.	Undeter- mined.
North.....	46	22	62	111	221	8	12
South.....	42	23	45	99	192	7	10
Whole Sun..	88	45	107	210	413	15	22

For the years 1913 to 1917, inclusive, the total number of "regular" polarities is 872, with 33 exceptions and 99 undetermined cases. For the year 1917, the 15 exceptions to the rule include 1 faint marking, 2 unipolar spots with no flocculi, 1 very complex spot, 5 spots for which there are only single unchecked observations, and 6 well-observed spots.

INCLINATION OF THE LINES OF FORCE IN SUN-SPOTS.

When a Zeeman triplet in the spectrum of a spot near the sun's limb is examined with a Nicol and quarter-wave plate, a line can generally be found across the spot along which the red and violet components of the triplet are equal in intensity. In a symmetrical spot this line is nearly parallel to the limb. It represents the regions in the spot at which the lines of force are approximately normal to the line of sight.

In spots near the east limb this "neutral line" passes through the umbra, not far from its center. As the spot is carried toward the center of the disk by the sun's rotation, the line moves toward the following edge of the penumbra, and finally disappears. In large spots the neutral line can sometimes be detected just within the following edge of the penumbra when the spot is only 20° or 25° from the center of the disk. After the spot passes the sun's center, the neutral line reappears near the preceding edge of the penumbra, and moves toward the center of the umbra, which it would finally attain at the extreme limb if the observations could be made at this point.

Irregularities in the forms of spots, the presence of small companions opposite in polarity to the chief umbra, and other magnetic peculiarities such as are noted below, frequently complicate the observations, and affect the position of the neutral line. But its average change in position with longitude, determined from observa-

tions of a considerable number of spots, gives the approximate inclination of the lines of force in various parts of the umbra and penumbra. Thus we find, from 105 observations of 61 spots made by Messrs. Joy and Nicholson, the accompanying positions of the neutral line and the corresponding inclinations of the lines of force (taken as normal to the line of sight passing through the neutral line):

Longitude.	Position of neutral line.	Angle between lines of force and solar radius.
30° to 40°	1.7	55°
40° to 50°	2.0	45
50° to 60°	2.8	35
60° to 70°	3.4	25
70° to 90°	4.0	10

The position of the neutral line is given in terms of a scale in which 1 represents the outer edge of the penumbra (toward the limb), 3 the outer edge of the umbra, and 5 the center of the umbra.

These results indicate that the lines of force at the center of the spot lie in a plane passing through this center and the sun's axis. They do not show, however, whether these central lines of force are normal to the sun's surface or inclined toward the north or south.

The latter question can be answered by determining the relative intensities of the *n*- and *p*-components of a Zeeman triplet in different parts of a spot observed near the center of the sun. The results of such observations vary greatly among themselves, but in many spots the *p*-component is strong even at the center of the umbra when the spot is near the center of the sun. In such a case the central lines of force must be considerably inclined toward the north or south. In spite of the many anomalies hitherto encountered the investigation is being continued in the hope of finding a general law governing the inclination of the lines of force.

RELATION BETWEEN FIELD-STRENGTH AND SIZE OF SUN-SPOTS.

Preliminary observations made some years ago reveal a definite correlation between the area of a sun-spot and the strength of the accompanying magnetic field. Mr. Nicholson has studied the relation from much more extensive data, including more than 300 spots, and finds that the field increases rapidly with the area in the case of small spots. For larger spots the increase is much less marked and the field seems to approach asymptotically an upper limit in the neighborhood of 3,500 or 4,000 gaussess. These results are based upon the iron λ 6173, of Rowland intensity 5.

GENERAL MAGNETIC FIELD OF THE SUN.

The preliminary results of a study of the Zeeman effect due to the sun's general field were published in Contribution No. 71, and have

been commented on in previous reports. These investigations have been continued, and an account of the search for additional lines showing the effect and of a study of the apparent variation of field-strength with level in the solar atmosphere has now appeared as Contribution No. 148.

Measures of displacements are given for 26 additional lines, belonging to the elements iron, chromium, nickel, vanadium, and titanium; 18 other lines, all of them susceptible to the influence of magnetic fields in sun-spots, show no measurable shift. The 26 lines, which through changes in position indicate the presence of a magnetic field, confirm the results in Contribution No. 71, and seem to place beyond reasonable doubt the conclusion that the sun behaves approximately as a uniformly magnetized sphere, with its magnetic axis slightly inclined to the solar axis of rotation and a polarity corresponding to that of the earth.

Laboratory data are available for 27 of the 30 lines known to be influenced by the sun's general field. Combined with displacements observed in the solar spectrum, these yield for each line a value of the field-strength at the magnetic pole. The results show that the field decreases with increasing values of the Rowland intensity of the respective lines. Since line-intensity increases with the level at which the various lines originate, it would appear that the strength of the sun's general field falls off rapidly with increasing elevation in the solar atmosphere.

Using Mitchell's observations of the flash spectrum, we find that the field now accessible to observation lies within the bounding surfaces of a thin shell in the solar atmosphere, whose thickness seems to be of the order of 150 km. Certain necessary corrections improve the internal agreement and leave outstanding as discordant only 2 of the 27 lines. With proper allowance for peculiarities in the behavior of different elements and in the Zeeman effect for individual lines, the results indicate that definite values of the calculated field-strength correspond to definite levels in the solar atmosphere.

Systematic errors in the measured displacements varying with the intensity of the spectral lines might explain the observed dependence of field-strength upon line-intensity; but there is no indication of the existence of such errors, and the internal evidence, on the other hand, is strongly in favor of the hypothesis of changing field-strength with changing level.

The anomalous behavior of the lines which show no displacement is not satisfactorily explained. Because of possible peculiarities of pressure, temperature, and electrical conditions necessary for the emission of these lines, they may originate outside the very limited region within which it has been possible thus far to observe the sun's general field.

The underlying causes of the sun's general magnetic field remain obscure. The evidence bearing on the local-whirl hypothesis is unfavorable to its acceptance as an adequate explanation of the existence of the field.

The investigation for determining the position of the sun's magnetic axis and its period of revolution about the solar axis of rotation is now approaching an end. Mr. van Maanen has measured 325 additional spectra, which completes the series, about 2,500 in all, photographed on 74 days between June 8 and September 25, 1914.

The provisional reductions have been finished by Miss Wolfe, who has done all of the extensive numerical work connected with the investigation. The least-squares solution for the inclination, period, and epoch have been revised, but with no essential modification of the results previously reported. The data will now be discussed by zones of heliographic latitude in order to see if the sun's field deviates appreciably from that of a uniformly magnetized sphere.

SOLAR ROTATION.

The series of solar-rotation observations is now in its fifth year. In accordance with the original plan, the same instruments, observers, and measurers have been employed, and it is hoped to continue them throughout the sun-spot cycle.

The variations during the period 1914 to 1918 show no evidence of periodicity and apparently depend upon temporary local conditions in the solar atmosphere and in particular upon the high differentiation of the sun's surface furnished by a solar image 420 mm. in diameter.

The slight indications of changes in the sun's rotation shown in the past are of such an order that they may in great probability be referred to temporary conditions then prevailing in the sun or to other circumstances of the observations.

The reflecting-prism system in use consists of three prisms each 2 mm. long, two of the prisms receiving light from one limb and one from the other limb. By rotating the spectrograph, the east and west limbs are interchanged with respect to the prism system. It was hoped by such an interchange to obtain a check upon the observations, but differences of several per cent often appear. These differences are real, for upon exposures taken in immediate succession, with interchange of prisms, they may amount to 6 or 7 per cent, while the individual lines are measured with a mean deviation of a third of 1 per cent. Moreover, they must be due to solar conditions. In using the red region of the spectrum it was found that the atmospheric lines are undisplaced upon plates showing extraordinary displacements of the solar lines. Further, observations with a duplicate prism system and an image 164 mm. in diameter, in which case the integrating

action is much greater, show normal displacements, while simultaneous observations on the large image show great irregularities.

An important result appearing in the course of the investigation is that a short series of observations may lead to misleading conclusions, and that in attacking such questions as possible differences between the solar rotation in the two hemispheres, or the variation with latitude, observations should cover extended periods of time.

The differences in rotation depending upon line-intensity or level shown by $H\alpha$ and the strong magnesium lines have been confirmed by observations upon the high-level H and K lines of calcium and the low-level lines of the nitrogen (cyanogen) band in the same region. These two groups of lines represent the most extreme differences in level with which we are at present acquainted, and should give the widest range in rotation. At the equator the H and K lines show displacements 10 to 15 per cent greater than those of the weak band lines, and for higher latitudes the differences increase, while the $H\alpha$ lines, according to the measures of Mr. Adams, give at the equator a velocity only 3 per cent higher than that derived from the reversing layer.

WAVE-LENGTH INVESTIGATIONS.

A number of problems are dependent upon a knowledge of precise values of the wave-lengths of the lines of iron in the solar spectrum. These are being measured in international units, both at the center and the limb, with the aid of the iron standards derived with the interferometer and an iron arc from which the pole effect is eliminated, supplemented by intervening lines whose wave-lengths are being concurrently determined with the spectrograph.

THE GREEN [CORONAL LINE AT THE 1918 ECLIPSE.

The observations by Mr. Adams and Mr. St. John for the determination of the absolute wave-length of the green coronal line and the rotation of the corona were only partially successful, since, owing to clouds, the spectrum of the corona was obtained only at the east limb of the sun.

The instrument used was a prismatic spectrograph of 40 inches focus, having a dispersion of 6 Å per millimeter at λ 5300. The slit was placed in coincidence with the sun's equator on an image 2 cm. in diameter, and just before totality a comparison spectrum was obtained by exposure on an iron arc, a simple occulting arrangement cutting out the region of λ 5303. The comparison spectrum has made it possible to determine the absolute wave-length of the green line to a high degree of accuracy, aside from the influences of rotation and local movements. The spectrum of the line is very weak and gives the impression that with a stronger exposure it might appear less simple in structure.

The plate has been measured by Mr. Adams, Miss Ware, and Mr. St. John. The results found by the use of the Hartmann formula, corrected for the motion of the earth, are:

Adams.....	5303.205	angstroms
St. John.....	.204	
Ware.....	.203	
Mean.....	5303.204	Rowland System
or.....	5303.022	International System

As this value represents the wave-length at the east limb, it is subject to an unknown correction due to rotation. If, however, it be assumed that the rotation of the corona is of the same order as the rotation of the higher chromosphere, namely, that on the east limb it is approaching the earth with a velocity of 2 km. per second, the correction is $+0.035$ A, making the Rowland and International wave-lengths 5303.239 and 5303.057 A, respectively. The main value of the present determination is that it establishes the wave-length of the green coronal line in terms of iron-arc standards and furnishes a basis for comparison with future similar observations.

TOTAL SOLAR ECLIPSE OF JUNE 8.

The plan of observations for the total solar eclipse of June 8 was based upon certain specific problems arising from our experience in solar work during recent years. Since most observers at previous eclipses have used apparatus of moderate power for spectroscopic investigations, it seemed desirable in the present case to employ instruments capable of yielding results of higher precision and more nearly comparable with those obtained with the solar spectroscopes in regular use. Moreover, essentially all the values for the wave-lengths of the bright lines in the spectrum of the flash are relative in character and provide no information regarding the possible displacements of these lines with reference to the dark lines of the Fraunhofer spectrum. Accordingly a slit spectrograph was designed, having an apparatus for producing a comparison spectrum of the iron arc which could be used for reference purposes.

When completed, the equipment for the expedition comprised the following instruments:

1. A photoheliograph with an aperture of 8 inches and a focal length of 30 feet for direct photography of the corona.
2. A wide-angle camera with an aperture of 4 inches and a focal length of 18 inches for photographing extensions of the coronal streamers.
3. A concave grating spectrograph of the objective type with a focus of $10\frac{1}{2}$ feet for a study of the spectrum of the flash and the corona, particularly in the ultra-violet.
4. A slit spectrograph of 18 feet focal length with a plane grating of 7 inches aperture for the determination of accurate wave-lengths of the lines in a portion of the flash spectrum.
5. A three-prism slit spectrograph of the auto-collimating type for an investigation of the rotation of the solar corona and the wave-length of the green coronal line.
6. A small camera with apparatus for studying the polarization of the corona.
7. A camera provided with a silvered-quartz lens for photographing the corona in light transmitted by the silver band.
8. A small refractor and polarizing eye-piece for visual observations.

Light was supplied to all of these photographic instruments except the concave-grating spectrograph by the 30-inch mirror of the Snow telescope. The apparatus was grouped in a very compact form about the cœlostæt mounting. A small plane mirror of speculum metal was attached to the upper end of the polar axis to furnish light for the concave grating and a concave mirror of 27 feet focal length was used to form the solar image upon the slit of the 18-foot spectrograph. For the prismatic spectrograph a lens was employed giving a solar image about 2 cm. in diameter.

In the selection of a site for the expedition, consideration was given both to records of weather conditions and to the facilities for the transportation of the apparatus, a most essential feature in view of the congestion of freight shipments. The elevation of the site was also of importance, particularly for work in the ultra-violet portion of the spectrum. Green River, in western Wyoming, on the main line of the Union Pacific Railroad, at an altitude of about 6,000 feet, was finally selected. Mr. Ellerman, and Mr. Jones, our superintendent of construction, arrived at the site about three weeks before the eclipse and began the erection of the piers and the assemblage of the apparatus. The remainder of the party, consisting of Messrs. Adams, Anderson, Babcock, St. John, and Professor Brackett, of Pomona College, reached Green River on May 31. Mr. Hale, Miss Margaret Hale, and Lieutenant Abetti of the Italian army joined the expedition on June 7.

The sky on the morning of the day of the eclipse was remarkably transparent, but shortly after noon cumulus clouds began to form in the west. The disk of the sun was entirely clear at first contact, but shortly afterward was obscured by a large cloud which moved slowly toward the east. This became much less dense near the end of the total phase and the brilliant prominences surrounding the sun were readily visible. The outer corona, however, could not be seen with certainty, and at no time was more than a small proportion of the coronal light available. Within a few minutes after third contact the cloud passed completely.

The observations were carried out in full according to plans, and the development of the negatives showed that more results had been obtained than might have been expected under the conditions. All of the direct photographs showed excellent detail in the corona and prominences, the longest exposure taken throughout totality being especially valuable. The short-focus camera, the polarizing apparatus, and the ultra-violet quartz lens all yielded results of considerable interest.

The spectroscopic observations, which were much more exacting in their requirements for full illumination, were interfered with greatly by the cloudiness at the time of total phase. Valuable results, however, were obtained with the concave grating spectrograph, a large number

of lines being photographed in the spectrum of the prominences and the upper chromosphere. Certain features connected with the radial motion of one of the prominences appear to be of exceptional interest. The negative secured with the prismatic spectrograph showed a faint line on one side of the solar image in the position of the green coronal line. While no measures of the rotation of the corona are possible, a determination of the wave-length of this line has been made which appears to be of a high order of accuracy.

AN ATTEMPT TO DETECT THE CORONA WITHOUT AN ECLIPSE.

Two methods of detecting the corona in full sunlight were tried by the Director many years ago. The first involved setting the second slit of a spectroheliograph on the center of a dark line in the solar spectrum. This would produce a reduction in the brightness of the sky without diminution in the light of the corona, assumed to be derived, not from a bright line, but from the continuous spectrum. This failed on Pike's Peak in 1893 and on Mount Etna in 1894. The second method required the use of a sensitive bolometer, arranged differentially to measure the relative radiation of the coronal streamers and the sky between them. This also failed in several trials, and Abbot's results at the total solar eclipse of 1900 indicated that the coronal radiation was insufficient to be measured in sunlight with a bolometer.

At the recent total eclipse of June 8, Dr. Joel Stebbins, using a potassium photo-electric cell, obtained large deflections corresponding to the total radiation of the corona (including, presumably, the chromosphere and prominences). This suggested to the Director the possible use of the photo-electric cell to detect the corona in full sunlight, and when Dr. Stebbins was consulted he thought favorably of the plan. A series of experiments has accordingly been made on Mount Wilson by Mr. Ellerman.

Two photo-electric cells were mounted in a metallic box with double walls. The box was supported on the massive circular head of the 75-foot spectrograph, at the focus of the 150-foot tower telescope. When observing, the solar image (about 16.5 inches in diameter) is made concentric with the spectrograph head, which can be rotated in position angle, carrying the photo-electric cells around the sun's image. Both cells are exposed to the sky outside the sun through adjustable apertures, the centers of which are equidistant (usually about 2') from the sun's limb. The cells are so connected with the electrometer as to give deflections corresponding to the difference in radiation received by them. If one were on a coronal streamer and the other on the sky between two streamers, the radiation would be unequal, and it was hoped that we might detect by this means the difference due to the added radiation of the corona.

The apparatus is fairly sensitive, giving a deflection of about 25 divisions when one cell is exposed to the image of the moon at last quarter, the other to the neighboring sky (in daylight). At maximum sensitiveness the insertion of a piece of clear plate-glass above one cell, producing a loss of 8 or 9 per cent, causes a deflection of about 80 divisions of the scale. At this sensitiveness, however, there are continual fluctuations of 5 or 10 divisions near the sun, making the measurement of very small differences impossible. The work will be continued with improved apparatus.

It is perhaps barely possible to send meteorological balloons, carrying automatic photographic apparatus, directed toward the sun by a gyrostat, and finally controlled automatically by the heat of the sun's image, to a height sufficiently great to allow the corona to be photographed without an eclipse. But the technical difficulties would be considerable.

INVESTIGATION OF STARS AND NEBULÆ.

OBSERVING CONDITIONS.

The weather conditions for observations at night on Mount Wilson during the year ending August 31, 1918, were above the average. The months September to December 1917 inclusive gave an unusual amount of clear weather. Observations were carried on with the 60-inch reflector during all of 206 nights and a part of 91 nights, while on 68 nights no observations were made. Out of 3,591 hours of darkness the telescope was in use 2,418 hours or 67 per cent of the time. The total exposure time for the year was 71 per cent of the observing time and 48 per cent of the hours of darkness; 63 per cent is the average observing time during the hours of darkness for the past six years.

The mirror was resilvered in September, April, and August. Statistics for each month, the conditions of seeing (on a scale of 10), and the wind velocity as noted each night are shown in the accompanying tables.

The self-recording anemometer installed on the Snow telescope building last year was moved on July 10, 1918, to the top of the 150-foot tower. This location, which is nearly 100 feet higher than the former one, and well above all obstructions, gives a more accurate record of the air-movement over the mountain-top. Readings made so far indicate an increase of from 40 to 50 per cent in the mean annual velocity, which at the old location was about 7 miles per hour. The highest velocity recorded during the past year was 36 miles on March 7 and April 19. The total precipitation for the year was 28.93 inches and the total snowfall 34.5 inches. The highest temperature was 97° F. on August 3, the lowest 18° F. on February 19.

Seeing (nights).	Wind (nights).
1. 36	Very high. 3
2. 49	High. 12
3. 37	Brisk. 31
4. 67	Moderate. 67
5. 54	Light. 134
6. 34	Calm. 110
7. 8	
8. 3	

Date.	Hours of darkness.	Hours clear.	Hours cloudy.	Hours lost silvering and repairs.	Hours of exposure time.	Observations.		
						All night.	Part of night.	None.
1917.								
Sept.....	295	256	39	10	178	23	5	2
Oct.....	336	259	77	.....	206	19	9	3
Nov.....	330	227	103	.....	161	18	8	4
Dec.....	346	265	81	.....	197	19	9	3
1918.								
Jan.....	346	154	192	2	118	9	10	12
Feb.....	308	131	177	.....	88	8	8	12
Mar.....	324	155	169	.....	123	15	6	10
Apr.....	286	151	135	16	118	13	8	9
May.....	266	177	89	.....	137	17	8	6
June.....	230	204	26	.....	103	23	6	1
July.....	255	217	38	.....	146	24	5	2
Aug.....	269	222	47	8	151	18	9	4
Totals for year..	3,591	2,418	1,173	36	1,726	206	91	68
Mean for 6 years	2,284	1,307	.....	1,618	190	90	85	

PHOTOGRAPHS OF NEBULÆ AND CLUSTERS.

A considerable number of photographs of spiral and irregular nebulæ were made by Mr. Ritchey at the primary focus of the 60-inch reflector. Among these were N.G.C. 1023, 7479, and 7782, Messier 81, H.V. 44, and H.I. 199. Eight photographs of the Andromeda nebula and five of Nova Persei were also obtained. The exposure-times on these objects varied from 30 to 330 minutes.

The study of the photographs of the Andromeda Nebula has resulted in the discovery of six additional novæ, one of which was found by Dr. Duncan in August of this year. The number of novæ in this nebula found from the Mount Wilson photographs now amounts to eight.

The announcement by Professor Barnard of a nebula near Nova Persei of 1901 led to the photography of this star with plates of different sensitiveness and with various exposure-times. The negatives showed the presence of a sharply defined continuous ring of nebulosity about the star, 16" in diameter. No certain evidence of motion was found on the successive photographs.

Mr. Pease obtained 12 photographs, mainly of spiral and gaseous nebulæ, during the autumn of 1917, with exposure-times varying from 20 to 320 minutes. These were as follows:

N. G. C.

- | | |
|--------|---|
| 955 | Spindle type. Variable? |
| 1186 | Supposed variable. No change since 1914. |
| 1491 | Faint, irregular. |
| 1555 | Very faint, irregular, with change since Nov. 1916. |
| 1700 | Nebulous patch 0'5×0'8 with strong center. |
| 2024 | Gaseous, faint and irregular. |
| 2245-7 | Irregular nebulæ in dark lane. |

- N. G. C.
- 2274-5

Very faint, with relatively bright nuclei.
- 2288

Several small faint spirals including N. G. C. 2888-91, 2894.
- 2359

Gaseous, irregular. Lies in Milky Way.
- 2964

Right-handed spiral, 2968 same, 2970 nebulous spot.
- Nova Persei

Nebulous ring just seen on 10-minute exposure.

JUPITER'S NINTH SATELLITE.

An ephemeris of Jupiter's ninth satellite was computed by Mr. Nicholson for the 1917 opposition. The satellite was found near the computed place on two negatives taken by Mr. Shapley with the 60-inch reflector. The positions were measured on these plates. The orbit is being carried forward by the method of special perturbations.

MEASUREMENTS OF PARALLAXES AND PROPER MOTIONS.

At the 80-foot focus of the 60-inch reflector 320 photographs with 447 exposures were secured by Mr. van Maanen as follows:

	Plates.	Exposures.
For parallax	245	372
For proper motion	65	65
Miscellaneous	10	10

The measures and reductions were completed for 26 fields, thus giving a total of 80 finished fields. While most of the objects were stars with proper motions less than 0".5 annually, of magnitude 5 to 7 and of later spectral types, the following nebulae and peculiar stars were also included:

Object.	Type.	Relative π .	P. E.
Nova Persei No. 2.	O	+0".007	$\pm 0".004$
B. D. +36°3956	O	-0.005	0.006
Barnard's Star			
of large P. M.	Mb	+0.519	0.006
N. G. C. 224 . . .	Spiral . . .	+0.004	0.005
" 2392 . . .	Planetary.	+0.020	0.003
" 5194 . . .	Spiral . . .	+0.005	± 0.008

Parallaxes have now been determined here for three planetary nebulae, viz, N. G. C. 2392, 6720, and 7662; including the value given by Newkirk for N. G. C. 6720, we derive the following absolute magnitudes of their central stars: +6.1, +8.1, and +9.4, respectively, or, in the mean, +7.9. This result is strikingly close to the mean absolute magnitude, +6.9, found for the three novae at minimum, for which parallax determinations are available. In both cases we seemingly have bright-line stars of faint absolute magnitude, while ordinary stars of type O have very high luminosities.

The conclusion mentioned in the last report, viz, that the systematic errors of the parallaxes measured at Mount Wilson can hardly surpass 0".003, is corroborated by the results for the additional fields.

In the search for faint stars of large proper motion, for which purpose most of the middle of the nights available for parallax work are used, three additional objects were found, two of them being companions of brighter stars of known large proper motion; they are—

Object.	Mag.	δ 1900	δ 1900	μ	π	M	Distance.
Anonymous.....	12.3	0 ^h 43 ^m 52 ^s	+ 4° 55'	3".01	.....	.....	.....
Comp. of Lal. 5490...	12.6	2 56 31	+61 22	1.13	0".045	10.9	5860
Comp. of 55 Cancri..	13.0	8 46 44	+28 42	0.54	0.061	11.9	1360

The magnitudes in the accompanying table are photovisual values derived by Mr. Seares; adopting for the two companions the parallaxes found for the brighter stars, we derive the absolute magnitudes and the distances from the principal stars (in astronomical units) given in the table.

A few spectra of faint stars were photographed with a small spectroscope attached at the 80-foot focus. They include the first star of the above table whose spectrum is found to be F₀, a result corroborated by the color-index determined by Mr. Seares, namely, +0.57. The object must therefore be either of very low luminosity for an F-type spectrum or else it must have an exceptionally large velocity. As soon as the parallax is known we shall be able to decide which is the case.

STELLAR PHOTOMETRY.

The observational part of the investigations in stellar photometry by Mr. Seares and Mr. Shapley includes 650 photographs, all made with the 60-inch reflector and distributed as follows: Selected Areas, 154; clusters, 183; variable stars, 55; color photographs of stars, 219; miscellaneous, 39.

PHOTOGRAPHIC MAGNITUDES FOR THE SELECTED AREAS.

Very satisfactory progress has been made with both observations and reductions. With the exception of three intercomparison and three polar comparison plates, the photographs for the original program, including Selected Areas 1 to 115, are complete. For the additional zone of 24 areas at -15° declination, 72 per cent of the observational work has been finished. Of the 924 photographs required for the entire program, 50 remain to be secured.

Relative magnitudes have now been obtained for 123 of the 139 areas, and for each of these regions Professor Kapteyn has been supplied with a sequence of provisional standard magnitudes to be used for the reduction of the Durchmusterung photographs of the Selected Areas. In addition, the final magnitudes, which are obtained

by adding the zero-point corrections to the relative magnitudes, have been formed for the first 67 areas, and the zero-point reductions for areas 68 to 115 are ready for the least-squares adjustment.

It is highly important that the final magnitudes should form a homogeneous system, in zero-point as well as in scale. To this end all the areas of each zone are intercompared, and at intervals of 4 hours in right ascension comparisons are made directly with the North Polar Standards, whose zero is the point of reference for the entire system of magnitudes. The zero-point determinations are therefore subject to certain closing conditions, similar to those occurring in triangulation operations, which may be expressed by the general statement that the algebraic sum of the zero-point differences along the closed circuit connecting any series of areas must be zero. Thus, for the zone at 45° , intercomparison photographs connect the successive steps in the circuit Pole, 20, 21, 22, 23, 24, Pole (the numbers are those of the areas involved), and 5 other similar circuits, each of whose summed zero-point differences must be zero. Further, there is the condition, superfluous so far as the adjustment is concerned, that the zero-point differences around the zone itself must also be zero.

To illustrate the accordance of the results, the closing errors now available, expressed in hundredths of a magnitude, are given in the accompanying table. In view of the number of steps in the circuits—usually 6, though the zone circuits include 12 at 75° and 24 for the other zones—the internal consistency appears to be very satisfactory.

Circuit.	75°	60°	45°	30°	15°	0°
1	0	+11	+24	- 5	.....	.....
2	+ 6	+19	+22	+19	+18	.....
3	0	+ 7	-12	-31	+ 1	- 5
4	0	-16	+ 1	-15	+ 4	- 1
5	-13	-14	-31	+ 5	- 7	- 1
6	-11	+ 1	-15	- 2	+ 2	- 2
Zone.	-18	+ 8	-11	-29	.....	.....

The reduction of the closing errors to zero is accomplished by the usual least-squares process for the discussion of conditioned observations. The results for each zone are adjusted separately, excepting those for 0° and -15° , which, because of the nature of the conditions, must be treated as a unit. The number of unknowns in each solution is 12 per zone. The resulting corrections for adjustment average ± 0.03 mag. For the 4 zones now complete, the maximum correction is 0.07 mag.

The extensive measures and reductions involved in this investigation have been continued by Miss Joyner, Miss Richmond, and Miss Winn. Miss Carolyn Burns and Miss Helen Burns have each given a part of the year to this work, and Miss Wolfe has frequently assisted with the reductions.

PHOTOVISUAL MAGNITUDES FOR THE SELECTED AREAS.

Plans for this investigation by Mr. Seares and Mr. Shapley have been outlined in previous reports. The observations have been continued, and 120 of the 257 photographs required have now been obtained. The measures, which have been made by Miss Winn and Miss Helen Burns for the greater part, are nearly complete to date.

INVESTIGATION OF THE COLOR OF STARS.

The annual report for 1916 included an account of some preliminary experiments by Mr. Seares on the measurement of the color of stars by a method which seems not to have been used before. Several successive exposures are made on an isochromatic plate with exposure-times forming a geometrical progression. Owing to the relatively low yellow-sensitiveness of such plates, the resulting images are largely due to blue and violet light, and are called "blue" images. Two or more additional exposures on the same plate through a yellow filter register the intensity of the yellow light. The ratio of the exposure-times necessary to produce blue and yellow images of the same size, or more conveniently the logarithm of this ratio, which is easily derived from the observational data, is a measure of the star's color. Several sources of error depending upon variations in the color-curve of the plate and other peculiarities in the photographic process immediately suggest themselves, but by suitable precautions they are easily controlled.

The colors of the North Polar Standards to magnitude 15.5 have been determined by this method and compared with the color-indices obtained from the investigation of their photographic and photo-visual magnitudes.* The agreement is excellent and demonstrates the usefulness of the method, which has the advantage of being both precise and expeditious.

In the meantime, much observational material relating to various problems has been accumulated and is now under discussion. Among other questions the dependence of color upon absolute magnitude in stars of the same spectral type has received much attention. For red stars the phenomenon is important, the difference between giants and dwarfs amounting to 0.5 or 0.6 mag. in the color-index. The relation of color to spectral type for constant absolute magnitude is also being studied, and in this direction numerous peculiarities require consideration. The spectroscopic investigations by Mr. Adams have shown that many features of the general spectrum which commonly follow the changes in the hydrogen lines in the normal succession of types do not in all cases show the usual correlation, and for many stars the type determined from the hydrogen lines differs notably

* Proceedings National Academy of Sciences, 3, 29, 1917.

from that derived from the general spectrum. The behavior of the color in such cases is of interest, and probably of importance, in view of its relation to temperature.

In this connection it may be remarked that Mr. Seares and Mr. Shapley have found that in certain Cepheid variables the color seems to be closely correlated with the spectral type as indicated by the hydrogen lines. Both vary periodically with the changes in brightness, while the general spectrum, as shown by the observations of Mr. Adams and Mr. Joy, remains nearly or quite constant.

THE PERIOD-LUMINOSITY CURVE OF CEPHEID VARIATION.

A very remarkable relation between the apparent magnitudes and periods of Cepheid variables was first pointed out by Miss Leavitt for 25 stars of the small Magellanic cloud. Mr. Shapley has further investigated the relation, which is in fact a correlation of period with absolute luminosity, and finds that it holds for the isolated variables of the galactic system and for the Cepheids, whether of the ordinary kind or of the "Antalgol" type, in at least six globular clusters. On the basis of light curves of more than 200 variables, a definitive period-luminosity curve has been obtained which gives uniquely the absolute magnitude of a typical Cepheid when its period of light variation is known. Since the parallax of a star is a simple function of its absolute and apparent brightness, the distance of a Cepheid, or of any stellar system containing such variables, is immediately obtainable from determinations of period and apparent magnitude.

The linear formula connecting logarithm of period and magnitude, as suggested by Miss Leavitt, is found to be a first approximation only. The adopted curve indicates a definite lower limit for the absolute brightness of Cepheid variables; and from a study of the luminosity curves in globular clusters this same limit appears to be closely related to the blue end of the giant series. In other words, typical Cepheid variation is apparently impossible, except for giant stars of low density. While the double-star theories of Cepheid variation afford no plausible explanation of the period-luminosity curve, a pulsation hypothesis appears competent to interpret at least its general features.

PHOTOMETRY OF STAR-CLUSTERS.

In last year's report on Mr. Shapley's investigation of star-clusters, reference was made to the determination of the relative distances of globular systems that contain typical short-period variable stars. The period-luminosity curve described above is at the basis of the most reliable method for the determination of their absolute distances. Through the development of methods for other classes of stars and the use of the marked correlations between the parallax, the brightness, and the diameter of cluster images on photographic plates and charts,

it has now been possible to derive estimates of the absolute parallax of all known globular clusters. Their distances greatly exceed those previously appearing in stellar studies, and the analysis of their spatial distribution brings to light numerous interesting points that have some bearing on the problem of the structure of the universe. In particular, it appears that the globular clusters are secondary organizations as compared with the whole galactic system, which in volume is at least a hundred thousand times that commonly accepted heretofore. Various synopses of the observed results and their interpretation are cited in the bibliography accompanying this report. Some of the more interesting features may be summarized as follows:

1. The mid-galactic region, an equatorial segment some 100,000 parsecs in diameter and 4,000 parsecs thick, contains practically all the isolated stars, open clusters, planetary and diffuse nebulae of which we know, but is essentially devoid of globular clusters and spiral nebulae.

2. The globular clusters are congregated to both sides of this galactic zone and there is some evidence that they are disrupted and scattered when they enter the dense stellar regions. It is suggested that the open galactic clusters are the remnants of globular systems that have entered the equatorial segment.

3. The center of the galactic system, which is in the direction of the star clouds of Sagittarius, is many thousand parsecs from the solar system.

4. The globular clusters vary in distance from 6,500 to nearly 70,000 parsecs.

5. The total number of known globular clusters is now 75, a systematic examination of faint suspected objects having yielded during the year only 6 new ones, all of which are very remote.

6. Through investigations of colors in clusters more distant than 50,000 parsecs, the upper limit of the coefficient of the scattering of light in space has been still further reduced.

7. An observational test of the speed of spectral evolution emphasizes the fact that unknown sources of energy are involved in the radiation of stars.

GALACTIC PLANES IN GLOBULAR CLUSTERS.

That the typical globular cluster is not spherical, but oblately spheroidal, has become evident from studies of star-distribution on Mount Wilson photographs. The somewhat flattened form is revealed by an elongation of the diagram, in polar coordinates, of the density of the stars; and occasionally the elongation can be detected on our plates merely from an inspection of the photographic image. It now appears that on good photographs of small scale (the Franklin-Adams Charts, for instance) the direction of elongation may be directly

estimated with about the same certainty that it can be derived from the laborious counts of thousands of stars. The accompanying tabulation shows the close agreement of the two methods, and justifies the extension of the work by means of estimates to the southern clusters that are unavailable for work with the Mount Wilson telescopes.

Cluster.	Position angle of major axis.	
	Counts.	Estimates.
M 5	55°	50°
M 13	125	130
M 15	35	20
M 19	15	15
M 22	25	25
M 28	50	45
M 53	160	170

Using the Franklin-Adams charts to supplement Mount Wilson plates, Mr. and Mrs. Shapley have now studied the form of 41 globular systems and have examined the orientation of the major axes with respect to the plane of the Galaxy. The images of about one-fourth of the systems appear to be nearly circular, a result to be expected from a random distribution of the assumed galactic planes. Two or three clusters are decidedly asymmetrical, but the remainder show distinct and approximately symmetrical ellipticity.

A THEORY OF STAR-STREAMING.

The center of the galactic system, as outlined by the globular clusters, lies in a direction 90° from the center indicated by studies of the motions and luminosities of the brighter stars. Moreover, the first center is more than 100 times as distant as the second. Investigating the probable meaning of this discrepancy from the standpoint of the larger galactic system, Mr. Shapley finds that a large, open, flattened star-cluster exists in the neighborhood of the sun, with its central plane inclined about 12° to the galactic plane; its center is some 50 parsecs to the north of the mid-plane of the Galaxy, as defined by distant stars and the galactic clouds. The investigation also yields information relative to the extent of the cluster and its spectral constituency.

We thus come to the rather obvious hypothesis that the phenomena of star-streaming are simply the results of the motion (as seen from our moving position in the solar system) of this local cluster through the general star-fields of the galactic system, supplemented by the internal orbital motions of the cluster stars. The sun, probably a field star, is by chance near the center of this immense moving system, which contains a majority of the conspicuous stars in the sky, including nearly

all of those in Orion, Scorpio, and Centaurus. Apparently the hypothesis is confirmed by practically all the observational and statistical data bearing on the motions and distribution of the nearby stars.

VARIABLE STARS.

As a by-product of the determination of the distances of globular clusters, the parallaxes of 140 isolated Cepheid variables have been derived by Mr. Shapley. The accuracy depends on that of the observed apparent magnitudes and on the reliability of the period-luminosity curve; unless some quite unsuspected systematic error is present, the accuracy is at least as high as that of trigonometric parallax measures of the nearer stars, although the Cepheids, with few exceptions, are beyond the sphere of practical trigonometric work. Most of the Cepheids at present known are intermediate in distance between the naked-eye stars and the nearer globular clusters and Milky Way clouds. The study of the distribution in space reveals little that is new. Some of the faint shorter-period Cepheids are outside the equatorial segment that is devoid of globular clusters. The longer-period Cepheids supply a valuable but provisional determination of the distance of the sun north of the galactic plane.

Mrs. Shapley has continued her computations of the orbits of eclipsing binaries. The systematic observations of the variables in the Orion nebula have been continued by Mr. Shapley, and the colors of a considerable number of these variables and their comparison stars have been measured by Miss Davis, who has assisted in the work on clusters and variables throughout the year. A sequence of comparison stars for the novæ in the Andromeda nebula has also been measured. In various globular clusters Miss Davis has found some new variable stars, probably of the Cepheid type. Mr. Benioff has undertaken the determination of photographic light curves with the 10-inch portrait lens of a group of Cepheid variables in the star-clouds of Sagittarius. The variations in the velocity, spectrum, and light of the Cepheid variable SU Cassiopeiæ have been discussed by Mr. Adams and Mr. Shapley.

STELLAR SPECTROSCOPY.

In continuation of the plan of observations outlined in the annual report of last year, a large proportion of the stellar spectroscopic work has been devoted to determinations of the absolute magnitudes and the radial velocities of certain selected lists of stars. Especial attention has been given to the stars listed in the *American Ephemeris*, since among these are many of the most luminous objects, intrinsically, of which we have any knowledge. Since the radial velocities of most of these stars are known, comparatively few measurements of velocity have been made. A sufficient number, however, has been determined

to furnish an adequate basis of comparison with the results of other observers.

The list of relatively faint stars of very large proper motion has been under observation throughout the year. Many of these stars are of exceptional interest from the standpoint both of radial velocity and of luminosity, some remarkably high motions in space having been found among them. As a supplement to the stars in this list and in the *American Ephemeris*, we have added to the observing program a considerable number of stars of intermediate proper motion selected from the catalogue of Boss. The importance of these stars lies in the evidence which they furnish with regard to the dependence of velocity upon absolute magnitude, and the division of the more advanced types of spectrum into the giant and dwarf classes.

Several short lists of stars have also been added to those under observation. Among these are: (1) a list of Cepheid variables; (2) a considerable number of the fainter Algol variables; (3) stars with recent parallax determinations; (4) a few visual double stars.

The number of photographs of spectra obtained during the year September 1, 1917, to September 1, 1918, is 1,130, distributed as follows:

American Ephemeris stars.....	266
Stars of large proper motion.....	234
Stars selected from Boss's Catalogue.....	322
Miscellaneous.....	308

Of these photographs, 141 are of stars fainter than the eighth magnitude visually, while 146 are of Nova Aquilæ No. 3.

RADIAL VELOCITIES.

The radial velocities of 160 stars have been determined during the year from measurements of three or more photographs of their spectra. Observations on several hundred other stars have been partially completed. Some of the more interesting results for specific stars are as follows:

1. The orbit of the spectroscopic binary Boss 46 has been determined from the reduction of 34 spectrograms and the results have been published. The hydrogen and helium lines show a variation of 450 km. and the calcium lines of about 20 km. in a period of 3.5225 days. The motion of the system as given by the hydrogen and helium lines is -45 km., which differs by 20 km. from that indicated by the calcium lines.

2. The star A. G. Berlin 1366 has a radial velocity of $+339$ km., the highest constant velocity so far observed for any star. It is of interest to note that the second largest velocity, -325 km., that of Lalande 1966, is of nearly the same amount, but negative.

3. The spectrum of the eclipsing variable W Ursæ Majoris has been investigated at different portions of its phase. The spectrum of both

components is visible and appears to be of about type F8. The lines, however, are extraordinarily wide and diffuse. The maximum relative velocity of the two stars is about 330 km.

4. The Algol variable TT Aurigæ shows a range of velocity for the principal component of over 400 km.

5. Measurements of spectra of three of the cluster-type variables, made in conjunction with Mr. Shapley, show exceptionally high radial velocities for stars of this spectral type. The two stars SU Draconis and SW Draconis have radial velocities of -193 km. and -74 km., respectively, at maximum of light. RS Boötis has a velocity of -51 km. at a similar phase.

6. Observations of the Algol variable Boss 1646, recently discovered by Schwab, show the presence of two spectra of closely the same type. The relative velocity of the two components at maximum is 240 km. The period is 2.52 days, or double that first announced from the photometric observations.

DETERMINATION OF SOLAR AND STREAM MOTION.

An extended investigation of stars of the more advanced spectral types has been carried out during the year by Mr. Strömberg relating to the correlation between absolute magnitude, on the one hand, and radial velocity, the solar motion, and stream motion on the other. Some of the main results may be summarized as follows:

1. There is a steady increase in average radial velocity with decreasing absolute brightness, a result in confirmation of that described in the report of the previous year.

2. The K term appears to be positive for the giant stars and negative for the dwarf stars.

3. The following values of the constants of the solar motion have been derived from an investigation of the velocities of 1,405 stars of advanced spectral types:

$$A = 270.9 \pm 3.3 \quad D = +29.2 \pm 3.4 \quad V_0 = 21.5 \pm 1.0 \text{ km.}$$

The constants are independent of the absolute magnitudes of the stars employed.

4. An appreciable asymmetrical distribution of the average radial velocities has been found, indicating that the directions of maximum velocity do not lie in exactly opposite directions, but are inclined to one another by amounts which depend upon the distances of the stars involved.

5. The tentative suggestion is made that the properties of the surface representing the average radial velocities may be explained on the assumption that the stars are moving mainly around the center of the galactic system, with a preferential motion in the galactic plane.

SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX.

The absolute magnitudes of several hundred stars with spectral types between A5 and M have been determined during the year.

These include both the relatively bright stars of the *American Ephemeris* and the catalogue of Boss, and the faint stars of large proper motion, most of which are of intrinsically low luminosity. The publication of a list of 50 stars with parallaxes measured by Schlesinger, and the additions to the number of trigonometrically determined parallaxes made by van Maanen and others, have aided in the calibration of the curves used in the spectroscopic reductions.

A material change has been made in the method of determination of the absolute magnitudes of the Cepheid variables. A study of the spectra of this class of stars, to which reference will be made presently, has shown that the intensities of the enhanced lines are quite abnormal for stars of this spectral type and that many other characteristics are peculiar. Accordingly the reduction formulæ employed in the case of stars of a less-advanced type of spectrum, in which the enhanced lines are prominent, have been tried for stars of the Cepheid class and appear to give consistent results. The general effect of this change is to make the absolute magnitude of these stars somewhat brighter than those obtained previously.

A computation of the absolute motions in space of about 1,000 stars with magnitudes determined by the spectroscopic method is now in progress. By a statistical treatment of this large amount of material, using the radial velocities, proper motions, and, so far as possible, the trigonometric parallaxes, it is hoped that several criteria will be obtained for further tests of the accuracy of the spectroscopic determinations.

NOVA AQUILÆ No. 3.

The independent discovery of this star by Mr. Joy on the night of June 8 and the prevalence of favorable weather made it possible to secure an extended series of observations of its spectrum from a very early stage. With the exception of June 18 and 30, photographs were made on every night between June 8 and July 1, and previous to September 1 a total of 176 negatives had been obtained. A considerable number of these cover the less refrangible region of the spectrum between $H\beta$ and $H\alpha$.

The measurement and reduction of the photographs is still in progress and reference can be made to only a very few of the results.

1. Probably the most interesting feature of the spectrum is the appearance on June 10 of a large number of fairly narrow and well-defined dark lines. At first it did not seem possible to identify these lines, but on comparison with a photograph of the spectrum of α Cygni (a star with extraordinarily prominent enhanced lines) it was found that nearly all of them were present in both spectra. The elements represented include iron, titanium, chromium, strontium, and some others. Only the strongest of the arc lines appear, and these but faintly. About 100 lines in the region between λ 4000 and $H\beta$ have been identified with certainty.

2. Measurements of the wave-lengths of these lines show that they are displaced toward the violet end of the spectrum by amounts varying from 20 Å at λ 4000 to 24 Å at $H\beta$, the displacement being proportional to wave-length. The shift of the less refrangible component of the hydrogen and helium lines (when both components are present, agrees with these values. Interpreted in terms of radial velocity, this displacement would correspond to a motion of approach of 1,500 km. in the gas producing these lines. Although velocities of this order should be accepted with reserve, it is most difficult to conceive of any physical cause other than motion of the source which could produce displacements of this magnitude proportional to wave-length and at the same time leave the lines comparatively narrow and well defined. It now seems probable, from an examination of the photographs of the spectrum of Nova Geminorum No. 2 of 1912, that a similar displacement was present, but of about half the amount.

3. The radial velocity of Nova Aquilæ No. 3, as determined from the narrow absorption lines K, H, D_1 , and D_2 , is -15 km.

4. The first evidence of the presence of the chief nebular line at λ 5007 was found on the photograph of June 20, only 12 days after the discovery of the star.

SOME SPECTRAL CHARACTERISTICS OF CEPHEID VARIABLES.

A study of the spectra of a number of the more prominent Cepheid variables shows certain well-defined peculiarities which appear to be characteristic of these stars as a class. Among them we may refer to the following:

1. The enhanced lines are exceptionally strong, being more prominent at maximum than at minimum light.

2. The hydrogen lines also are exceptionally intense. This peculiarity is so marked that it results in an estimate of spectral type, when the hydrogen lines are used, very different from that obtained from the more general characteristics of the spectrum, such as the intensities of the metallic arc lines.

3. The variation in spectral type between maximum and minimum of light for the Cepheid variables is mainly a variation in the intensity of the hydrogen and the enhanced lines, and not in the spectral lines as a whole.

4. At maximum of light, the maximum of intensity of the lines in the hydrogen series shifts toward the violet in the same way as that of the continuous spectrum.

MINOR INVESTIGATIONS.

Among the results of other investigations we may refer briefly to three:

1. The spectrum of α Ceti has been observed throughout a considerable portion of its period. Recently we have been able to identify

a number of the bright lines which appear in the spectrum near minimum of light with lines of iron belonging to the low-temperature groups of *a* and *b*. It seems probable, therefore, that the atmosphere of the star near minimum undergoes a fall in temperature which favors the appearance of these lines. A similar behavior is found for the magnesium line λ 4571. This behavior may prove to be characteristic of the other stars of the Md type.

2. The spectra of the individual components of several visual double stars have been investigated; if the difference in magnitude is not too great, it is possible, under favorable observing conditions, to obtain results for stars separated by $1''.5$. In a large majority of cases the fainter component has the more advanced type of spectrum and frequently is of very low intrinsic brightness. It is evident, therefore, that only in the case of relatively near stars would many of the systems appear binary, the fainter component becoming invisible at great distances on account of low absolute brightness. This may account in part, at least, for the results found by Perrine, indicating a dependence of spectral type of the components of double stars upon distance.

3. In continuation of the investigation of the effect of absolute magnitude upon the intensity of the continuous spectrum in the more and less refrangible portions of the spectrum, about 700 spectrograms have been compared by Mr. Sanford with suitable standard photographs. The absolute magnitudes of nearly all of these stars are available from spectroscopic determinations.

SPECTROSCOPY OF NEBULÆ AND STAR-CLUSTERS.

Investigations of the spectra of nebulae and star-clusters have been carried on by Mr. Pease and Mr. Sanford with the small focal-place spectrograph and the 60-inch reflector. Forty-one spectrograms have been measured for radial velocity by Mr. Sanford, among them a number of photographs of selected stars in clusters as well as of spiral and gaseous nebulae.

Observations both of radial velocity and of spectral type are of especial interest in connection with star-clusters because of the investigations by Mr. Shapley and others on the colors of the stars in objects of this nature. As an illustration reference may be made to the star listed by Bailey as No. 95 in his list of variables in the globular cluster Messier 3. A spectrogram made with an exposure time of 11 hours indicates that its spectrum is of advanced type and contains bright hydrogen lines. A large color-index has been found for this star by Mr. Shapley, and Bailey has shown that it can not be included among the numerous short-period variables of the cluster type. A second spectrogram failed to show the bright lines. It is possible that the star is a variable of type Md.

Reference may be made to the following determinations of radial velocity:

Messier 3 (7 stars).....	-190 km.
N. G. C. 1700.....	+800±
N. G. C. 3379.....	+850

The two nebulae belong to the class of small objects which have for a nucleus a condensation almost of stellar form. The traces of outlying nebulosity are insufficient to give any definite information concerning the spiral structure.

A spectrogram of the Andromeda nebula was obtained by Mr. Pease with an exposure time of 79 hours, the slit being set along the major axis. The multiple-comparison device was employed and comparison spectra were photographed at different distances along the nebular lines. The measurement of the plate showed marked evidence of rotation. At a distance of 150" from the nucleus, opposite points in the nebula have radial velocities which differ by 170 km. For intermediate points a linear relationship between velocity and distance is indicated, the values being given by the formula

$$y = -0.48 x - 316$$

in which y is the radial velocity in kilometers and x the distance in seconds of arc. A previous photograph taken with the slit set along the minor axis showed no evidence whatsoever of rotation and thus furnished valuable evidence for the accuracy of the results. The radial velocity of the nucleus of the nebula derived from the two spectrograms is -306 km.

PHYSICAL LABORATORY.

INSTRUMENTS.

The chief addition to the laboratory fittings during the year has been the installation of a very complete switchboard by means of which excellent facilities of current-supply are obtained in all parts of the laboratory. Thus alternating current at 52, 104, and 208 volts and direct current from generators of 12 and 17 k. w., used either singly or in series, are supplied to all the instrument pairs; 3-phase current and special connections for the high-tension transformer and the large electromagnet are also provided on the switchboard, the knife switches of which have an interlocking system to prevent cross-connection of different circuits.

The repair of a slight fire damage in the transformer room, apparently resulting from an electrical storm, gave better fire protection to the building and an improved arrangement of the high-voltage connections.

The large high-tension transformer has been entirely rebuilt. The secondary voltage is now approximately 150,000, and tests showed the insulation capable of standing an 8-inch spark in air. Four variations of the primary windings are available and all parts of the apparatus are readily accessible for repairs.

ELECTRIC-FURNACE INVESTIGATIONS.

Besides some work in completing the examination of furnace spectra of elements of the calcium group, the electric furnace, in connection with the 15-foot concave-grating spectrograph, has been used for the study of the manganese spectrum from λ 2800 to λ 6600, and for the iron and titanium spectra, especially for the ultra-violet region as far as λ 2800 not covered in the work already published. About 60 furnace spectrograms have been made for various temperatures and a considerable part of the work of examining and classifying the very numerous lines of spectra has been done. This involves a comparison with arc and spark spectra which have also been photographed for these elements, and in the case of iron a comparison with the results of Hemsalech for the flame spectrum. The grouping of lines in the various sources and at the different furnace temperatures is very pronounced, and special attention is paid to numerous lines which are relatively strong in the furnace spectrum.

Other work by Mr. King has been in connection with the cathode luminescence spectra, the examination of the spectra of several chemical samples, and tests of plates bathed with dicyanin. Solar, arc, and furnace spectra as far as λ 9200 were photographed with plates thus sensitized, and it appears quite feasible to extend the regular study of spectra to a limit still farther in the red by means of these plates.

PRODUCTION OF SPECTRA BY CATHODE LUMINESCENCE.

The experiments by Miss Carter have been a continuation of previous work, the method being to vaporize a substance through the impact of cathode rays in a high vacuum and observe the spectrum given by the vapor bombarded by the cathode stream. The considerable heating of the apparatus in these experiments has introduced many difficulties in addition to those usually met in working with high vacua. The use of a quartz chamber, with most of the fittings of the same material, was necessary on this account. In the later experiments the spectra of iron, titanium, manganese, cadmium, and magnesium have been produced by this method, and the previous results for calcium checked by the use of a prism spectrograph. The largest number of lines was obtained for manganese, about 125, while about 100 lines of titanium were photographed. In distribution, the luminescence spectrum is relatively rich in the ultra-violet, this being the chief resemblance to the spark spectra. With calcium, cadmium, and magnesium the method has brought out enhanced lines, but with other elements examined the spectrum is more like that of the arc. The work is still in progress, and the material when completed may be expected to show many features of interest.

SECONDARY STANDARDS OF WAVE-LENGTH.

Miss Margherita Burns and Miss Brayton, acting under the direction of Mr. Babcock, have continued the determination of secondary standards of wave-length in the iron spectrum from photographs made by him in 1917.

Since the last annual report they have separately completed the measurement and reduction of 35 plates and the reductions of 30 plates previously measured. This brings the total up to 79 plates, nearly all of which have been measured and reduced by two observers independently. The remarkable accordance of their measures is demonstrated by the fact that 25 fairly representative lines belonging to the list of adopted secondary standards, including some of low weight, show a mean difference, without regard to sign, of only 0.0005 Å. Between the limits λ 3370 and λ 5662 we now have wave-lengths, obtained by the interference method, of 836 iron lines, a large proportion of which have been measured on more than 10 plates. The numerous new secondary standards thus made available are of considerable advantage in the concurrent determinations of wave-lengths by means of the plane grating, now proceeding under the direction of Mr. St. John. The accordance in the results attained by these two methods is so far very satisfactory, and it will doubtless eventually insure a thoroughly reliable system of standards.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

The greater part of the time of the drafting department has been given to the 100-inch telescope. The more important drawings and designs relating to this instrument and its accessories which have been prepared during the year include the mechanism for operating the louvers in the dome, the Cassegrain spectrograph, modified mountings for the coudé and Cassegrain mirrors, a revision of the design of the observing platform, the reinforcing ring for the Cassegrain cage, and a complete sectional assembly through the telescope and dome to be used for publication purposes.

Much time was also spent in the design and drafting for special apparatus used by the eclipse expedition, comprising three spectrographs and a photoheliograph.

The miscellaneous work has included a prism attachment for the 13-foot spectroheliograph, a new focal-plane spectrograph for the 60-inch reflector, attachments for the ruling engine, a solar stereoscope, a laboratory grating spectrograph, various assembly drawings, and numerous charts, etc., for the illustration of publications.

During the absence of Mr. Pease in Washington, the department has been in charge of Mr. Nichols, chief draftsman.

THE OPTICAL SHOP.

The work in the optical department, which has remained under the direction of Mr. Ritchey, has been much divided. The only large piece of work which has been finished is the Newtonian plane mirror for the 100-inch reflector, the polishing and figuring of which required between 7 and 8 months' time of one of the opticians, Mr. Kinney. In spite of the exceptional difficulties arising from its oval form (the diameters are 24 and 34 inches), a very fine figure has been attained. This mirror is $6\frac{1}{2}$ inches thick.

Several months' work has been done by Mr. Dalton on the large oval coudé plane mirror for the 100-inch reflector. The greater part of his time, however, has been spent on work for the government.

In addition, two 12-inch and three 9-inch plane mirrors have been finished for use on Mount Wilson. Two prisms have been made for use with the 13-foot spectroheliograph.

THE INSTRUMENT SHOP.

The work of the instrument shop has been under the direction of Mr. Ayers, foreman, while Mr. Jacomini has continued as chief instrument-maker. Over one-half of the entire time of the shop has been devoted to the construction of instruments and experimental apparatus relating to war service. Of the remainder, by far the largest part has been given to the 100-inch telescope and its accessories. The most important of these have been the Newtonian, coudé, and Cassegrain cages, the observing platform, and the Cassegrain spectrograph. Additional accessories have been the apparatus for silvering and burnishing the 100-inch mirror, two plate-holder attachments, devices for setting the telescope and reading the circles, and many smaller pieces of mechanism. Preparations for the solar eclipse of June 8 required rather less than 3 per cent of the working-time of the instrument shop.

Twelve outside precision micrometers and eight inside micrometers have been completed for the Bureau of Standards in addition to twelve micrometer heads and a graduated scale. The instrument shop has also constructed much apparatus used in experiments for the Navy and the Signal Corps of the Army.

Mr. Jacomini has devoted his time to the ruling-engine. The ruby thrust-bearing was finished by the end of 1917, and has been found to perform admirably. The ruling-tests showed the necessity of several minor adjustments, most of which have now been made, so that at the present time the machine is quite free from periodic errors. Investigation of errors of run and the very small accidental errors which are still present is now in progress. This involves the ruling of a number of 4-inch gratings, most of which will undoubtedly be useful optical instruments.

ONE-HUNDRED-INCH TELESCOPE.

Preliminary tests of the 100-inch telescope, arranged in the Cassegrain form, were secured early in November 1917 under moderately favorable conditions of observation. A number of objects, including the Moon, Saturn, and several stars were examined, and the tests showed conclusively that the great light-gathering power of the instrument will be used to full advantage under good observing conditions. An extraordinary amount of minute detail was seen in the case of the moon. The images, however, showed considerable flare which appeared to be due in part to temperature effects, and in part to imperfect collimation resulting from lack of rigidity in the support of the convex mirror of the Cassegrain combination. In order to obviate the latter difficulty a compression ring has been added to the tube section carrying this mirror. This affords ample rigidity, and the temperature control for the 100-inch mirror is now being completed. A periodic error of small amplitude and short period was observed in the driving of the telescope and is now under investigation. A most satisfactory feature of the telescope is the ample power of the driving-clock and the ease of control of the entire instrument.

The observing-platform has been partially reconstructed during the year, with a view to reducing its weight and aiding the convenience of operation. Essentially all of the smaller parts of the telescope have been finished and assembled and the electrical installation is now complete. It is our plan to use the telescope first in the Cassegrain form in conjunction with the spectrograph and plate-holder at the secondary focus. As in several other branches of construction work, the progress of this instrument has been greatly delayed by the large amount of time devoted in the machine-shop to activities arising from the war.

CONSTRUCTION WORK ON MOUNT WILSON.

The greater part of the construction work on Mount Wilson has been of a minor character and has consisted in repairs and improvements of the buildings and grounds. A considerable amount of labor has been devoted to the clearing of fire-breaks and the elimination of the more inflammable material surrounding the buildings. In addition reference may be made to the remodeling of the Hooker cottage; the building of an approach to the 100-inch telescope dome; an extension of the steel roof of the power-house; repairs of the roof of the Monastery; and much miscellaneous painting, including the dome of the large reflector.

The construction of the high-tension transmission line by the Southern California Edison Company was completed during the autumn of 1917, and since that time regular use has been made of the electrical energy supplied by this line, our own power-plant being employed

during periods of interruption of the service. This large supply of power has been of the greatest value, in view of the heavy demands of some of the construction work upon the 100-inch telescope. Since much of the electrical energy of the Edison Company is obtained from hydraulic installations, the use of this source of power is most desirable, in view of the necessity for economy in all kinds of fuel at the present time.

As in previous years, Mr. Dowd, engineer in charge of the power-plant, has built and installed most of the additional electrical equipment. This has included the large switch-board and automatic switches for the Pasadena laboratory; numerous electrical controls for the operation of the 100-inch and the 150-foot tower telescopes; and the rearrangement of much of the apparatus and connections in the power-house for use with the transmission line.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

Emphasis has frequently been laid in the Nutrition Laboratory upon the importance of utilizing the cooperative efforts of the major portion of the Laboratory staff in large research projects rather than of laying stress upon minor though important problems to be carried out independently by various workers. Thus far the Nutrition Laboratory has had valuable experience in the first method of attack in two instances: (1) the cooperative study of the man who was completely deprived of food for 31 days, in which not only the entire staff but 7 or 8 voluntary workers were occupied; (2) in the research outlined in the alcohol program, to which substantial contributions are made each year.

Since the annual report for 1917 was written, the study there outlined on the influence of a prolonged restriction in diet upon human vitality and efficiency has been carried out with the cooperation of the entire staff. In this research every member of the staff spent the larger part of his or her time from September 1917 to August 1918 upon the accumulation of data, the computation and tabulation of results, and the preparation of the report of the investigation for publication. Entirely aside from the character and amount of work accomplished, abundant proof has been obtained that such a project results in a unification of all departments of the staff of the Laboratory, which can be secured in no other way.

Contrary to popular impression, a research laboratory is no more exempt than are other fields of activity from the influence of the national unrest that has permeated all departments of American life, particularly in the last year and a half. In the case of the Nutrition Laboratory, however, this spirit of unrest has been accompanied by an intensity of purpose which has resulted in a concentration of effort on the part of every member of the staff never heretofore experienced, and which has been clearly reflected in the history of the Laboratory the past year. During this time, nearly all the activities of the Laboratory were made secondary to the greater project of studying under-nutrition. As shown in subsequent pages, it has not been necessary to discontinue the work on some of our well-established researches, and progress has been made in these to a certain extent, but the construction and testing of apparatus and the additions to the equipment have been, almost invariably, incidental to the larger research on under-nutrition. As a result, there has been a marked decrease in the direct additions to equipment, in the number of minor researches carried out, and in the reports of previous researches prepared for publication.

*Situated in Boston, Massachusetts.

ADDITIONS TO EQUIPMENT.

Respiration chamber for treadmill observations.—To study the energy required for the work of forward progression, as in walking at a moderate pace, the treadmill extensively used in previous researches was employed in the research on low diet and a special form of respiration chamber was constructed to fit over the treadmill. The entire apparatus, with accessory features, is described in the report of the low-diet investigation. This respiration chamber has given excellent results and will ultimately be used for preliminary studies in connection with researches on the effects of more rapid walking.

Reconstruction of the calorimeter for small animals and infants.—The respiration chamber for small animals and infants, which has been in successful use for two years, is now being reconstructed in a more substantial form, with important modifications and betterments. When the reconstruction is completed and the apparatus fully tested, it will be used for direct calorimetric measurements with small animals and infants.

Recorder for adequacy of motor adjustments.—In our psychological laboratory we have given a great deal of prominence to the time relations of reactions and motor coordinations. No satisfactory means has been at hand for taking account simultaneously of the adequacy or accuracy of these processes. The apparatus which Dr. Miles has under construction could not be completed early enough to serve in the study of undernutrition, but will doubtless be of great usefulness in future investigations. The subject views the scale of a wattmeter and is required to keep the indicator at zero. A disturbing element produces an unknown and unpredictable series of fluctuations in the wattmeter which the subject must compensate, while the duration and extent of his plus and minus errors are integrated by two other meters, and a curve-drawing instrument provides a graphic record of his performance.

COOPERATING AND VISITING INVESTIGATORS.

Owing to the fact that Dr. Elliott P. Joslin entered the National service as major in the Medical Corps and was subsequently assigned to a hospital in France, the research on diabetes which, in previous years, has been carried out with his cooperation was discontinued. The equipment which had been installed for this work in the special laboratory at the New England Deaconess Hospital was removed and has been actively employed in other researches. Immediately prior to his embarkation for field service in France, Dr. Joslin published a "Diabetic Manual." This manual embodies the results of his extended experience with diabetics and a system for treatment which has been based in part upon the experimental data accumulated in connection with the Nutrition Laboratory.

Dr. Fritz B. Talbot has cooperated in the investigation upon the metabolism of normal children from 2 to 12 years of age, which was carried on in the room specially equipped by the Nutrition Laboratory at the New England Home for Little Wanderers. The cordial cooperation of the superintendent of the home, Dr. Frederic H. Knight, has been very much appreciated.

Dr. J. Arthur Harris, of the Station for Experimental Evolution, has completed his statistical elaboration of data on basal metabolism obtained at the Nutrition Laboratory and the results are now in press.

Recognizing the great importance of determining the influence of food taken between meals, Mrs. Cornelia Golay Benedict has cooperated in a careful study of the calorific values, as determined with the bomb calorimeter, of many of the extra foods which are becoming more and more a feature of the daily calorific intake of a large number of people.

Dr. F. W. Rolph, of the University of Toronto, spent several weeks at the Laboratory during the spring of 1918, studying various types of respiration apparatus in use here. By arrangement with Professor Andrew Hunter, of the University of Toronto, he secured a complete clinical respiration chamber constructed in the Nutrition Laboratory, as well as one of the new portable respiration apparatus. During his stay the Laboratory derived much profit from his counsel.

Dr. Paul Roth, of the Battle Creek Sanitarium, was actively identified in the research on undernutrition. Indeed, on account of the critical illness of Dr. Carpenter, it is safe to say that without Dr. Roth's cooperation the investigation would hardly have been possible.

INVESTIGATIONS IN PROGRESS.

Metabolism of normal children.—As considerable data had been accumulated on the basal metabolism of children from birth to 2 years of age, the extension of this study to children from 2 years of age to puberty was deemed necessary. Consequently, in cooperation with Dr. Fritz B. Talbot, a small clinical respiration chamber and accessory apparatus were installed in the New England Home for Little Wanderers and studies of the basal metabolism of children of both sexes were made continuously with the active assistance of Miss Inza A. Boles of the Nutrition Laboratory and Mrs. Dorothy A. Peabody. The accumulation of data has proceeded in an unusually rapid and satisfactory manner.

Studies of metabolism with varying environmental temperatures.—The popular conception of an intimate relationship between environmental temperature and heat loss and the importance of knowing the laws governing heat loss have led to an extended study of the influence of varying environmental temperatures upon metabolism. With the ordinary individual, especially in the nude condition, a slight lowering

of the temperature is accompanied by excessive involuntary muscular activity, usually in the form of shivering, which in itself produces a considerable increase in the metabolism. To eliminate this extraneous factor, an investigation has been conducted with a professional artist's model whose training has made it possible for her to withstand very cold environmental temperatures. In connection with this study of heat-production, studies have been made of water vaporized from the skin under various conditions, and particularly of the changes in skin temperature due to changes in temperature environment. Studies are also planned on the stimulating effect of various foods with different environmental temperatures. This investigation has been carried out with the active and intelligent cooperation of Miss Alice Johnson, assisted by Miss Mary D. Finn.

Metabolism of cold-blooded animals.—Although engaged the greater part of the year in the research on undernutrition, Mr. Edward L. Fox during the spring of 1918 was able to resume the investigation at the New York Zoological Park on the metabolism of cold-blooded animals. An effort was made to secure experimental data clearing up several obscure points noted in the earlier part of the research. In the summer of 1918 Mr. Fox entered the National service, and thus the continuation of this research has been indefinitely postponed.

Group studies of the energy requirements of normal individuals.—The sustained interest of the department of physiology of Simmons College, and particularly of Professor Alice F. Blood, made it possible for us, in the spring of 1918, to resume our observations on groups of young women from that institution. This cooperation has proved most profitable, both to the Nutrition Laboratory and to Simmons College, for not only have the results contributed greatly to our knowledge of the normal metabolism of women with various activities, but the whole research, and particularly the participation in it, have been of real value to the several classes cooperating. The study will be extended so as to include a wider range of physical activities each year.

The influence of recuperation upon metabolism.—The pronounced difference in the subjective feelings of all persons prior to and following the usual summer vacation has led to a special study of the basal metabolism of a group of volunteers to note differences, if any, in the metabolism under these conditions. With some 10 subjects Miss Alice Johnson and Miss Mary F. Hendry have been occupied in studying the basal metabolism with the clinical respiration chamber.

The calorific value of extra foods.—In a number of recent dietary studies, the investigators have recognized the importance of noting exactly the calorific intake of foods taken outside of the usual meals. Inasmuch as the energy intake from this source may be relatively large, Mrs. Cornelia Golay Benedict has begun an extended investigation into the calorific value, as determined by the bomb calorimeter,

of a variety of extra foods, such as crackers, chocolate, and particularly the products of the American soda fountain. It is planned to include in this study a considerable number of noonday lunches and certain bottled beverages. In this research Mrs. Benedict has been very intelligently assisted by Miss Marion L. Baker. A first report of this investigation has already been made and is reviewed in subsequent pages.

Comparison of respiration apparatus and breathing appliances for human subjects.—The development of the portable respiration apparatus noted elsewhere and the application of a half-face mask for respiratory exchange work offered an opportunity to Dr. T. M. Carpenter for an elaboration of his comparative studies of the respiratory exchange obtained with various breathing appliances and respiration apparatus. In addition, the question of the use of entirely untrained subjects was for the first time adequately studied. A series of comparisons of the respiratory exchange was obtained with 17 first-year medical students who had never had a breathing appliance attached to them. The portable respiration apparatus and a respiratory-valve apparatus (so-called Tissot) were used. The breathing appliances were the Denayrouse mouthpiece, the nosepieces devised by Benedict, and the Siebe-Gorman half-face mask. The measurements of the respiratory exchange were made in 10 to 15 minute periods, when the subjects were in the post-absorptive condition. The periods were so arranged that there was alternation between the two respiration apparatus and alternation between the breathing appliances. Twelve periods were made with each subject, and thus there was a duplicate with each breathing appliance with each respiration apparatus. Measurements were made of the carbon-dioxide elimination, oxygen absorption, pulse-rate, respiration-rate, and volume of lung ventilation per minute. The respiratory quotient and the volume per respiration were calculated; with the respiratory-valve apparatus the composition of the expired air was also determined.

The study showed that accurate results can be obtained with the majority of untrained, presumably healthy subjects, provided at least three periods on one day are made; that there is very little choice, if any, in the breathing appliance to be used, and that it depends mainly upon the preference and comfort of the subject; that both the portable apparatus and respiratory-valve apparatus give strictly comparable results for oxygen absorption and that the simplest, quickest, and most efficient method of determining the oxygen consumption of a subject at rest is by means of the portable respiration apparatus. The carbon-dioxide elimination as determined by the portable apparatus is slightly higher; consequently the respiratory quotient is higher than that determined by the respiratory-valve apparatus, this being due primarily to the greater volume of lung ventilation per minute with the portable respiration apparatus than with the respiratory-valve appa-

ratus. There is very little difference subjectively in either apparatus or breathing appliance.

The respiratory quotient with a closed chamber versus that with a breathing-appliance respiration apparatus.—It has been apparent for a number of years that there is a material difference in the respiratory quotients found with a Regnault-Reiset type of closed-circuit apparatus as compared with those found with a breathing-appliance respiration apparatus. An investigation has been begun by Dr. T. M. Carpenter to ascertain the cause of this difference. The clinical respiration apparatus devised in this laboratory has been used for the closed-circuit type and a combination of a half-face mask, valves, and spirometer has been employed for the breathing-appliance type of apparatus. Untrained medical students have thus far been used as subjects. The experiments are still in progress.

Physiological application of the modern gas-mask.—This laboratory is interested in all types of breathing appliances which can be used in studies of the respiratory exchange. The recent development of a gas-mask has given us an opportunity to compare the respiratory exchange with this appliance and that found by standard respiratory-exchange apparatus; a number of experiments of this character have been conducted by Dr. T. M. Carpenter.

Distribution of alcohol in tissues.—The investigation with human subjects, reported previously, upon the concentration of alcohol in urine when introduced by the mouth or per rectum showed that there was a fairly definite curve of concentration of alcohol in the urine from the standpoint of time, and that there might be differences according to the method of introduction. It is believed that the concentration of alcohol in the various tissues, urine, and blood will be of importance in interpreting the metabolic results of introduction of alcohol. An investigation has been started by Dr. T. M. Carpenter upon the methods of recovery of alcohol from tissues with reference to such a study. Experiments are now in progress upon the distribution of alcohol in tissues and fluids of various animals, depending upon the method of introduction, viz, respiratory tract and skin, by mouth, and per rectum.

PUBLICATIONS.

- (1) A portable respiration apparatus for clinical use. Francis G. Benedict. *Boston Med. and Surg. Journ.*, 178, 667 (1918).

The experience with pathological cases in the Nutrition Laboratory made it evident that a simple and accurate method for determining the respiratory exchange was needed which would lend itself to more general usage than either the complicated respiration calorimeter or the somewhat less complicated clinical respiration chamber. This led to the devising of the portable respiration apparatus which is a natural development of the universal respiration apparatus in its several forms. In the portable respiration apparatus, which is described in detail in this paper, the patient breathes into and out of a confined volume of air, which is circulated by means of a mechanical blower through a series of purifiers in which the carbon dioxide and water-vapor are absorbed. A spirometer provides suitable housing for the mechanical blower, acts as an expansion chamber for the fluctuating volume of air, and gives a measure of the changes in volume of air by means of direct readings of the level of the spirometer bell. Attachment to the subject may be made by a mouthpiece, nosepiece, or face-mask. The apparatus is mounted on a convenient stand, with casters, which enables it to be moved about a laboratory or hospital with perfect ease, requiring only connection with an electric socket.

The decrease in the total volume of air, as measured by the changes in level of the spirometer bell with slight temperature and pressure corrections, represents the amount of oxygen consumed by the patient during the experimental period, which may continue for 10 or 15 minutes. The oxygen consumption is thus determined without gas analysis, weighings of any kind, or the use of meters. The lungs of the patient are not required to force the air through the purifying vessels or to actuate valves of any kind, since this is done by the electric fan located in the spirometer; hence respiration through this apparatus is as nearly normal as possible. By indirect calorimetry the heat-production may be computed from the oxygen consumption. While primarily designed to give a measure of the oxygen consumption, since this is least affected by abnormal respiration such as may occur with hospital patients, an approximate measure of the carbon-dioxide elimination and respiratory quotient may also be obtained by weighing the absorbing vessels.

This apparatus was tested practically in the research on undernutrition, in which several hundred observations were made, determinations of the gaseous metabolism of seven of the subjects being obtained simultaneously nearly every day of the research. The subsequent careful test of this method of determining the respiratory exchange by comparison with some of the older and better-known types of respiration apparatus, which was made by Dr. Carpenter, is referred to in another part of this report. (See page 223.) The apparatus has been found to give very satisfactory results and thus makes it possible for observations of the oxygen consumption to be conducted in a clinic or a private laboratory without gas analysis or weighings.

- (2) The effects of a prolonged reduced diet on twenty-five college men. I. On basal metabolism and nitrogen excretion. II. On neuro-muscular processes and mental condition. III. On efficiency during muscular work. Francis G. Benedict, Walter R. Miles, Paul Roth, and H. Monmouth Smith. *Proc. Nat. Acad. Sci.*, 4, 149 (1918).

Although the accumulation of data in the low-diet research with a selected group was not finished until February 3, a preliminary report of the findings of this set of results was made before the National Academy of Sciences on

April 22, 1918. The following abstract differs slightly from the original report in that advantage is taken of the final calculations of results to change somewhat the figures therein incorporated. It seems unwise to continue using the old figures, which were given as preliminary data, when the actual results are at hand.

The report includes a discussion of the influence of the prolonged low diet upon basal metabolism and nitrogen excretion, the neuro-muscular processes and mental condition, and the efficiency during muscular work. Deferring until the appearance of the final detailed report the complete abstracting of the data therein, we may here emphasize the following tentative conclusions:

With a normal demand, prior to dietetic alterations, of 3,100 net calories, the net calories required for maintenance after the weight had been lowered about 12 per cent by reduced diet averaged about 1,950 calories, or approximately one-third less than the original requirement. One squad of 12 men subsisted for 3 weeks on 1,400 net calories without special disturbance.

At the end of the reduction in weight the actual heat output during the hours of sleep, as computed by indirect calorimetry, was approximately one-fourth less than normal. The heat output per kilogram of body-weight and per square meter of body-surface was 18 and 22 per cent, respectively, lower than at the beginning of the study.

Marked losses in total nitrogen were observed. In round numbers the men each lost approximately 150 grams of nitrogen. There is an intimate relationship between this so-called "surplus nitrogen" and the metabolic level. Removing the "surplus nitrogen," we believe, distinctly lowers the stimulus to cellular activity.

The nitrogen output per day at the maintenance diet of 1,950 net calories was about 10.5 grams. A control group of 12 men, living substantially the same life and eating in the same dining-room, but with unrestricted diet, showed a nitrogen output of 14 grams.

Pulse-rates as low as 33 were not unusual and daily counts of 32, 31, and 30 were obtained; at least one subject gave six definite counts on one morning of 29 per minute.

The blood-pressure, both systolic and diastolic, was distinctly lowered.

The rectal temperature was practically normal.

No noticeable discomfort was experienced by the subjects, except a feeling of cold. The men continued the usual college activities with no obvious reduction in stamina.

A second squad, when put for a period of three weeks upon a restricted ration of less than half their previous caloric consumption, showed a reduction in metabolism and a loss in nitrogen in proportionately the same degree as that shown by the first squad.

Seventeen separate psychological measurements were made with the men, 5 by the group method and 12 by the individual method. Typical results are given in table 1, in which the results obtained with normal diet are given in bold-face type. The experiment lasted 4 months, September 29, 1917, to February 3, 1918. From this table it will be seen that the accuracy in tracing gradually improved. With the control squad (see results under C. S.) it continued to improve on low diet, with no definite effect established. The same may be said with regard to addition.

With the strength of grip the results obtained with the diet squad (D. S.) were definitely below those for the control squad, but on the three reduction dates for the latter squad there was no definite change. Therefore the difference in level between the two squads can not be interpreted as due entirely to the low diet. The eye movements show a progressive reduction in speed

TABLE 1.—*Illustrative results from psychological measurements during prolonged reduction in diet.*

No. 1, tracing.		No. 4, addition.				No. 6, grip.		No. 14, eye movements.		No. 15, finger movements.	
Average errors per line.		Total columns in 10 minutes.		Per cent of error.		Average kilos for both hands.		Average time in sigma.		Number in 10 seconds.	
D. S.	C. S.	D. S.	C. S.	D. S.	C. S.	D. S.	C. S.	D. S.	C. S.	D. S.	C. S.
5.7	5.6	47.3	47.5	21.5	19.7	.....	.....	.....	.....	68.7	66.0
5.9	5.6	50.2	46.9	16.3	10.9	47.6	52.8	95	92	65.6	65.2
6.0	4.6	51.4	48.7	19.0	7.8	48.1	54.3	97	96	66.6	65.6
5.4	4.7	54.0	49.6	19.9	10.8	46.9	52.8	97	91	64.2	64.7
5.3	4.8	52.6	42.5	15.1	9.6	45.7	53.5	98	92	64.3	66.5
4.1	4.4	52.7	46.9	17.0	14.0	44.9	54.1	100	95	63.4	64.2
4.7	3.5	52.8	48.7	18.4	10.7	46.2	53.2	.....	.....	64.9	62.4
4.4	3.9	52.8	51.1	14.2	8.7	45.9	53.3	.....	.....	65.4	61.4
3.3	.....	53.4	.....	13.2	.....	45.8	.....	.....	.....	63.5	.....
3.3	.....	56.8	.....	11.7	.....	.....	.....	.....	.....	67.6	.....

amounting to about 5 per cent with the diet squad. The normal performance of the control squad was not regular, which detracts from the significance of the lengthening in the compared two low-diet sessions. The control and diet squads show a decline in the number of finger movements with the reduced diet.

Eleven men of the diet squad were pitted against an equal number from the college body in an arm-holding contest for endurance. The arms were held extended, palms down, at the level of the shoulders. The number of men who did not endure to the end of the period was practically the same in both squads; as a matter of fact, 7 men of the diet squad and 8 of the competing squad were still holding out their arms in the prescribed manner 60 minutes after the trial started. Whatever one may think of this as a real test of endurance, it is significant that the men who had been on reduced diet for 4 months were not appreciably inferior.

"Basing judgment on the more objective laboratory measurements, in general it must be concluded that a prolonged reduction in diet produces some decline in neuro-muscular activities, but this does not seem nearly as definite nor as large as the changes in metabolism and allied measurements. The psychological changes were not such as to materially interfere with a satisfactory discharge of the common duties of student life."

Of the various forms of muscular activity which might have been chosen for a quantitative study of the efficiency of the human machine under a prolonged period of reduced diet, that of walking was selected, since it is the most common and necessary exercise, the element of training is practically negligible, and the results can be expressed in common and well-understood terms. The subjects were all required to walk upon a treadmill in a closed chamber in which the respiratory exchange could be studied and the caloric output computed from the results obtained. On January 6 the control squad was studied prior to the diet restriction, and again on January 28 after 20 days of low diet. With the diet squad, only one observation was made, that at the end of the diet restriction, namely, on February 3. The results for the heat required per man per kilometer during horizontal walking, without taking into account the body-weight, are given in table 2. A marked decrease in the total heat required for walking is shown as a result of the diet.

TABLE 2.—*Reduced diet and heat required per man during horizontal walking, rate 69 meters per minute (2.5 miles per hour).*

Squad.	Condition.	Total heat required per man per kilometer.	Heat reduction from normal.
		<i>cal.</i>	<i>p. ct.</i>
Control	Normal	62.2	.....
Control	20-day diet..	53.5	14
Diet	4-month diet.	48.4	22

The energy requirement per kilogram of body-weight for walking one horizontal meter is given in table 3, in which calculation the basal metabolism, *i. e.*, that required to maintain the body while standing quietly, is deducted in all cases.

TABLE 3.—*Reduced diet and heat required per kilogram of body-weight in walking 1 horizontal meter.*

Squad.	Condition.	Heat per horizontal kilogrammeter.	Gain over normal.
		<i>g.-cal.</i>	<i>p. ct.</i>
Control	Normal	0.610	.....
Control	20-day diet..	0.561	8
Diet	4-month diet.	0.522	14

"The results of these experiments are quite positive and show a marked saving in the energy requirements for walking in favor of the reduced diet, whether considered on the basis of the gross energy expended, which represents the real cost to the individual and to the national food reservoirs, or on the basis of the energy required per horizontal kilogrammeter. Although the results here submitted are confined to one form of muscular activity, nevertheless it is believed that the quantitative results obtained would be duplicated if other forms of muscular work were studied."

(3) Physiological effects of a prolonged reduction in diet on twenty-five men. Francis G. Benedict. *Proc. Am. Phil. Soc.*, 57, 479 (1918).

In this paper, which was read before the American Philosophical Society in the spring of 1918 and is based upon observations made in the study of the effects of a prolonged reduction in diet, a semi-popular presentation is given of some of the important practical considerations which may be deduced from the results. It is emphasized that the data obtained indicate the legality of Professor Chittenden's conclusions with regard to the practicability of a low-protein diet, although it is pointed out that the minimum may not necessarily be the optimum protein. The fact that this group of 25 men underwent this rigid diet restriction and performed their college duties, both intellectually and physically, without obvious reduction in stamina, is taken as the basis of a suggestion that the civilian population may, without danger, for a relatively long period of time, materially reduce their food consumption by the simple process of weight reduction, weight reduction carrying with it lesser food demand. This applies particularly to the civilians not doing severe muscular work. The importance of underweight rather than overweight for

civilians is likewise emphasized, as well as the possibilities for the conscientious patriot to conserve food by weight reduction, since the element of danger in such reduction is extremely remote.

"Let no one (particularly if he be overweight) complacently say that he has done his share until some positive action for food restriction has been taken. Fortunately no special chemical analyses, no calorimetric devices, no physiological measurements are essential for the control of this factor, One has but to lower the body-weight gradually 10 per cent and adjust the food eaten to hold it at this level. The reduction in weight should cover a period of probably two to three months. It could be done in a considerably shorter time. When the weight is once lowered and the caloric intake adjusted to holding the weight at that level, the patriot may feel assured that he or she is really making some positive contribution toward food conservation and making it possible to send liberally to our allies and to our own men much-needed supplies.

"I can not feel that an alteration in the army diet is justifiable at present. It is bad policy 'to swap horses in the middle of the stream.' The fighting unit may well be exempted from innovations, but let the civilian population give this whole project a thorough, honest test, recognizing that while there may be, in certain cases, an element of hazard and in many cases an element of discomfort, the possibilities for danger in accomplishing a weight reduction of 10 per cent are negligible. The calories thereby saved are by no means negligible, and with the sum total of our population would feed an enormous army."

- (4) Physiological effects of a prolonged reduction in diet on twenty-five men. Francis G. Benedict. *Journ. Roy. Army Med. Corps*, August 1918.

Reprint of No. 3. See abstract of that paper.

- (5) Effets physiologiques d'une réduction prolongée du régime alimentaire expérimentée sur vingt-cinq sujets. Francis G. Benedict. *Bul. de la Soc. Sci. d'Hyg. Alimentaire*, 6, 442 (1918).

Reprint of No. 3. See abstract of that paper.

- (6) Energy metabolism of an amaurotic family idiot. Fritz B. Talbot. *Am. Journ. Diseases of Children*, 16, 39 (1918).

This paper gives the results of observations with a female child having amaurotic family idiocy and pyelitis. The girl was 2 years and 4 months old, had a height of 76 cm., and a weight of 6.41 kg. She was extremely emaciated and moved in bed only when disturbed by sound or touch. The muscles were thin and atrophic. The metabolism was determined in 3 half-hour periods with complete quiet. The heat produced per 24 hours, as calculated from the average results of these three periods, was 39 calories per kilogram. Per square meter of body-surface it was 700 calories on the basis of the Lissauer formula and 610 calories on the basis of measurements taken by the Du Bois linear formula. During the observation the rectal temperature was 97° F.

This child with amaurotic family idiocy presents an unusual and complicating situation, in which the very low metabolism may have been modified by the subnormal temperature, by emaciation, by the plane on which the girl was living, or by the disease; no simple explanation for these results is apparent. It is hoped that other records of the metabolism of amaurotic family idiots will clear up the doubtful points presented in this picture.

- (7) The energy content of extra foods. Cornelia Golay Benedict and F. G. Benedict. *Boston Med. and Surg. Journ.*, 179, 153 (1918).

A careful survey of the food consumption of various classes of individuals has shown that there is a striking tendency, particularly in recent years, for

a considerable portion of the total amount of food and drink ingested to be taken incidentally throughout the day and not as a part of the regular three meals. These food materials may be classified as "extra foods." Several studies of food intake made in recent years have proved that not far from 10 per cent of the total calories a day may come from this source. This fact is not generally appreciated even by the physician and student of dietetics, but should be taken into account in obtaining a true measure of the daily diet. Information regarding the caloric value of these extra foods has therefore great significance, for, as pointed out in this article, these extra foods may, in many instances, be actually the determining factor in obesity, while on the other hand, a diet somewhat deficient in calories may be legitimately supplemented by food taken in this way.

The article here abstracted is the initial report in a series of papers giving the results obtained in a study now in progress at the Nutrition Laboratory to obtain definite information regarding the caloric content of these extra foods by direct combustion in the bomb calorimeter. The energy content of many of the so-called "soft" or temperance drinks has also been studied and these observations will be continued. It is, furthermore, the purpose to study typical noonday lunches which are taken in the industrial centers by a large number of workers who do not eat their midday meal at home.

The extra foods considered in this article are the various forms of sweet chocolate, milk chocolate, and nut chocolate, a number of temperance drinks, including ginger ale and grape juice, and products of the American soda fountain, particularly the ice-cream sodas and college ices or "sundaes." With many of these foods, the nitrogen content was likewise determined. It is shown that while temperance drinks having a large admixture of water, such as ginger ale and possibly grape juice, do not add greatly to the caloric intake, the ordinary portions of sodas and college ices are of considerable significance. As a typical example of the possible number of calories obtained in these extra foods, which are for the most part neglected in a consideration of the caloric intake, a table of the original article is reproduced here, which gives the caloric value of a number of sundaes or college ices with the different combinations as served at the ordinary soda fountain. The energy content of these sundaes ranged per portion from 225 to 516 calories; thus it is perfectly possible to obtain 400 or even more calories of energy from an ordinary college ice.

Sundaes.

	Total calories.		Total calories.
<i>Chocolate ice cream.</i>		<i>Strawberry ice cream.</i>	
Chocolate sauce, walnuts.	327	Fresh strawberry sauce.	277
Chocolate sauce, walnuts.	516	Fresh strawberry sauce.	406
Chocolate sauce, walnuts.	433	Strawberry sauce.	257
Fudge sauce, walnuts.	412	Strawberry sauce and marsh-	
Marshmallow sauce, walnuts. . .	383	mallow.	412
Marshmallow and chocolate		<i>Vanilla ice cream.</i>	
sauce, walnuts.	429	Fresh strawberry sauce.	334
Maple sauce, walnuts.	419	Marshmallow sauce, walnuts. . .	350
Strawberry sauce.	235	Chocolate sauce, walnuts.	396
Strawberry sauce.	225	Marshmallow sauce.	251
		Chocolate sauce, nuts.	371
		Strawberry sauce.	304

Three samples of the popular ice-cream cone were found to yield from 82 to 132 calories. Of the chocolates studied, the plain chocolates had an average content for the 15 samples of 5.8 calories per gram, while both the 7 samples of milk chocolate and the 11 samples of nut chocolate showed an average energy content per gram of 5.7 calories. The calories per gram for the different varieties of crackers ranged from 4 to 5 calories.

The article concludes with a discussion of the calories found in these extra foods, emphasizing particularly the fact that such calories should not be disregarded in any consideration of the food intake. "500 calories, whether in the form of steak or in the form of ice cream, are the same so far as the supply of energy to the human organism is concerned. Indeed, 500 calories in the form of ice cream may have an actually greater effect upon obesity than 500 calories in steak, since in the latter case we have the stimulating effect of the protein to assist in burning up the calories and the fact that a portion of the calories from protein is excreted unchanged."

In consideration of the tendency of American legislation towards the prohibition of the manufacture and sale of alcoholic liquors and the important part that the so-called temperance drink plays in satisfying the demand for these extra foods, a note of warning is sounded against the curtailment of the manufacture and sale of the products of the American soda fountain.

(8) Effect of alcohol on psycho-physiological functions. Walter R. Miles. Carnegie Inst. Wash. Pub. No. 266 (1918).

The unique feature of this study is the comparison of results from two series of alcohol experiments, performed on the same subject and under identical laboratory conditions, but by different investigators. The importance of such repetition series of experiments is urged as fundamental to the establishment of trustworthy results in this field. These data supplement and amplify those reported by Dodge and Benedict on the "Psychological effects of alcohol" (Carnegie Inst. Wash. Pub. No. 232, 1915), and form another contribution on the psychological side under the tentative plan for alcohol investigation at the Nutrition Laboratory. The dose was 30 c.c. of absolute alcohol diluted with water and flavoring material to a total volume of 150 c.c. The normal and alcohol data were equal in amount and control doses were used on the normal days. The processes measured (which include a wide range) and the apparatus and technique employed were the same as those used previously. The subject who served in the repetition experiments treated of in this report was an adult male, 26 years old, the least promising of the normal group employed by Dodge and Benedict, who had found him to show the smallest general effect of the alcohol. The experiments were more intensive than in the previous series, covering as they did 5 hours per day for 6 consecutive days.

The general effect of the alcohol, as found in this second series, and shown in the table herewith, is quite definitely one of neuro-muscular depression. The variety of measurements provide 30 results which may be taken as indicators of the alcohol effect. Of this total, 27, *i. e.*, a ratio of 9 to 1, show inferior functioning of processes after the dose. There are 16 cases in which this change was less than 10 per cent and 11 cases in which it ranged from 10 to 37 per cent. There was some variation from day to day, but it appears that no one day exercised a predominating influence on the general findings.

The two series of results are in practical agreement as to the direction of the alcohol effect, and together they establish the fact that this subject (No. VI) was affected by alcohol in substantially the same way as five or six other men, although he clearly demonstrated certain individual peculiarities.

Appended material in the report supplies important data concerning the use of alcoholic beverages outside of the psychological laboratory by the subjects of Dodge and Benedict and the general effects of alcohol as reported by these subjects. There are also some recalculations of the previously published data.

Percentile effects of alcohol arranged in order of magnitude.

Measurements.	Second series. Av. of periods 2, 3, and 4.	Dodge and Benedict series (normal group).
Inferior functioning:		
Patellar reflex, amplitude of secondary (A') with 50-gram blow.....	37.5	38
Mean variation of eye-reaction time.....	27.1	.....
Mean variation of pulse cycles with finger movements.....	26.0	.....
Lid reflex, amplitude of secondary (A').....	24.7	104
Eye movement, horizontal distance in 5".....	20.0	.....
Lid reflex, amplitude of primary (A).....	19.7	10.7
Faradic threshold in β units required to stimulate the fingers.....	16.4	.....
Patellar reflex, amplitude of primary (A) with 30-gram blow.....	16.2	60.3
Eye-reaction time to peripheral stimuli.....	11.5	S. ¹ 5.4
Pulse-cycle duration, "average of other pulse data, Nos. 1 to 7".....	11.2	3.0
Pulse-cycle duration immediately before muscle tension.....	10.0	3.1
Eye-movement time required for turning from left to right through 40°.....	9.2	3.4
Pulse-cycle duration at time of finger movements....	8.1	.....
Faradic threshold in Z units required to stimulate the fingers.....	7.7	21.0
Lid reflex, latency of primary (L).....	5.4	5.9
Patellar reflex, latency of secondary (L') with 30-gram blow.....	4.5	4.0
Mean variation of memory saving.....	4.3	.....
Number of free finger movements performed in 8 seconds.....	3.7	8.9
Length of respiration.....	3.3	.....
Patellar reflex, amplitude of primary (A) with 50-gram blow.....	3.2	² (60.3)
Pulse-cycle duration after muscle tension.....	2.9	.....
Lid reflex, latency of secondary (L').....	2.7	6.8
Patellar reflex, latency of primary (L) with 30-gram blow.....	2.6	11.1
Pulse-cycle duration at the time of muscle tension....	2.2	4.1
Patellar reflex, latency of secondary (L') with 50-gram blow.....	1.7	² (4.0)
Mean variation of word-reaction time.....	1.7	.....
Patellar reflex, latency of primary (L) with 50-gram blow.....	1.0	² (11.1)
Superior functioning:		
Progress in memorizing four-letter words.....	2.5	1.4
Word-reaction time for four-letter words.....	4.4	0
Patellar reflex, amplitude of secondary (A') with 30-gram blow.....	17.0	² (38)

¹Superior with Dodge and Benedict.

²Dodge and Benedict made no distinction between intensities of stimulation for patellar reflex in their final summaries.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. BAUER, DIRECTOR.

GENERAL SUMMARY.

OCEAN MAGNETIC WORK.

The return of the *Carnegie* to her home port, Washington, D. C., on June 10, 1918, in order to go out of commission probably during the period of the war, is of special interest to all who have watched the progress of this vessel in the execution of her chief task—a magnetic survey of the oceans. After having been out of commission at Buenos Aires during the period March to November 1917, the *Carnegie* sailed from that port early in December 1917 on her homeward cruise, making a record western passage, for a sailing vessel, around the Horn to Talcahuano, Chile. She thence proceeded to Callao, Peru, and passing through the Panama Canal sailed for Newport News, Virginia, arriving there June 4, 1918. The scientific work accomplished is set forth on page 234. Table 2, pages 249–255, contains the preliminary results of the magnetic observations from December 1917 to June 1918. With this table there have appeared now in print all the results of our ocean magnetic work, 1905–1918, with sufficient accuracy for the practical purposes of mariners' magnetic charts.

Though the German government, before our entrance into the war, was being supplied promptly and continuously (the same as were other interested countries) with the magnetic data obtained aboard the *Carnegie*, no assurance was received from the German authorities that a vessel like the *Carnegie*, engaged in a world scientific mission for the welfare of all nations, would receive any special protection or assistance from her naval commanders.

It may be recalled in this connection that during a period of warfare almost a century and a half ago, France and the American Colonies, then (1779) at war with England, issued special instructions (see page 262) to their sea commanders to the effect that, if they fell in with Captain Cook's vessels returning from the South Seas to England, they were to facilitate their passage and show them every respect. The grounds for such enlightened instructions were that Captain Cook's discoveries were of general utility to all nations and of benefit to mankind in general. No similar instructions, as far as known, were issued by Germany to her naval commanders with regard to the *Carnegie* in spite of her peaceful and scientific mission for the good of all countries, and although it was well known in Germany that this vessel was returning from another world-cruise begun in 1915. The original plans for the *Carnegie* contemplated a return of the vessel to

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her home port in the spring of 1917; the necessity of detaining her at Buenos Aires, after declaration of war between Germany and the United States, not only caused a delay of a year in her return, but also prevented the completion of very important magnetic work in the South Atlantic Ocean.

Table 1 brings up to date the summary of the ocean magnetic work of the *Galilee* and the *Carnegie*, 1905-1918. It will be seen from the third column that the aggregate length of the three cruises of the *Galilee*, 1905-1908, was 63,834 nautical miles and of the five cruises of the *Carnegie*, 1909-1918, 189,176 nautical miles. The combined aggregate length of the cruises of the *Galilee* and the *Carnegie*, 1905-1918, is, accordingly, 253,010 nautical miles, or about 290,000 statute miles, or about $11\frac{1}{2}$ times the Earth's circumference. All of these cruises have been accomplished safely, with almost no mishaps and almost no loss of life, but three sailors being lost through careless acts of their own while off duty.

TABLE 1.—Summary of ocean magnetic work of the *Galilee* and the *Carnegie*, 1905-1918 (June).

Vessel and cruise.	Number.		Number of observed values.			Average time-interval, days.			Average distance apart, miles.		
	Days.	Nautical miles.	Decl.	Incl.	Hor. int.	Decl.	Incl.	Hor. int.	Decl.	Incl.	Hor. int.
<i>Galilee:</i>											
Cruise I, 1905...	92	10,571	74	58	59	1.2	1.6	1.6	143	182	179
Cruise II, 1906...	168	16,286	95	88	91	1.8	1.9	1.8	171	185	179
Cruise III, 1906-08.....	334	36,977	156	169	171	2.1	2.0	2.0	237	219	216
Totals for <i>Galilee</i>	594	63,834	325	315	321	1.8	1.9	1.9	196	203	199
<i>Carnegie:</i>											
Cruise I, 1909-10	96	9,600	98	68	69	1.0	1.4	1.4	98	141	139
Cruise II, 1910-13.....	798	92,829	858	648	643	0.9	1.2	1.2	108	143	144
Cruise III, 1914.	84	9,560	108	81	80	0.8	1.0	1.0	89	118	119
Cruise IV, 1915-17.....	487	63,401	867	480	479	0.6	1.0	1.0	73	132	132
Cruise V, 1917-18	122	13,786	224	116	116	0.5	1.1	1.1	62	119	119
Totals for <i>Carnegie</i>	1,587	189,176	2,155	1,393	1,387	0.7	1.1	1.1	88	136	136
Totals, <i>Galilee</i> and <i>Carnegie</i> ..	2,181	253,010	2,480	1,708	1,708	0.9	1.3	1.3	102	148	148

From plate 1 it will be seen that, except for certain regions, the Pacific Ocean between 60° north and 60° south has been quite thoroughly traversed by the *Galilee* and the *Carnegie*, the tracks of these two vessels, moreover, repeatedly intersecting. Instead of but a single

track,* passing through the central part of the Pacific Ocean, along which magnetic data were obtained, as was the case prior to the year (1905) when our ocean work began, there are now about 8 north-and-south tracks and about the same number running east and west. Not only can accurate magnetic charts for the use of mariners be constructed now, but also the requisite charts may now be prepared for investigation of some fundamental outstanding scientific questions concerning the Earth's magnetism.

For the North Atlantic Ocean we also now have information along a sufficient number of tracks to meet the mariner's practical demands and to assist in the solution of scientific questions. However, for the South Atlantic and Indian Oceans, additional cruises would have been desirable and could have been accomplished by this time had it not been for the interruption caused by the war.

As soon as the *Carnegie's* work may be resumed, it will be necessary to undertake further cruises, especially in the South Atlantic and Indian Oceans, and to secure crossings of the tracks in all of the oceans for the purpose of determining the changes to which the Earth's magnetic state is continually subjected. Since in the future cruises it will probably not be necessary to make the magnetic observations as intensively as in the past, it is hoped that there may be opportunity to take up other lines of ocean investigations which may again promise results both of practical utility and of scientific value.

ATMOSPHERIC-ELECTRIC WORK.

This work has been continued on the *Carnegie*, as have also the investigations and observations at Washington. Furthermore, special observations were made during the total solar eclipse of June 8, 1918, the stations being Lakin, Kansas, in the belt of totality, and at Washington, where the magnitude of maximum obscuration of the Sun was 74 per cent. For an account of the work under this head, see pages 238-239.

LAND MAGNETIC WORK AND ECLIPSE OBSERVATIONS.

The conditions caused by the war made it necessary to restrict the magnetic survey of land areas to the following work, all of which was successfully accomplished:

1. *Africa*.—Observer H. E. Sawyer led an expedition along the Upper Nile, through the interior of Eritrea to the port of Massawa, and thence partly along the Red Sea and partly along the Nile, arriving finally at Helwan, near Cairo, where he compared the magnetic instruments used by him with those of the British magnetic survey of Egypt. On his homeward journey, via the Pacific, he expects to reoccupy some of our previously-established stations.

*Thus Capt. Ettrick W. Creak, in his letter to the Institution, in which he indorsed the project of the Department of Terrestrial Magnetism, said: "The North Pacific Ocean is, with the exception of the voyage of the *Challenger*, nearly blank as regards magnetic observations."

2. *Asia*.—Observer F. Brown conducted an expedition in southeastern and eastern China, November and December 1917. He secured also a comparison of his instruments with those of the Jesuit Observatory at Lukiapang, near Shanghai. This is the second series of such comparisons of instruments at this observatory.
3. *South America*.—Observer Allen Sterling led an expedition in Central Brazil, along the Amazon River and tributaries. On his homeward journey he also reoccupied some stations in French, Dutch, and British Guianas, where the Department of Terrestrial Magnetism had made observations previously.

SPECIAL OBSERVATIONS.

4. *North America*.—In connection with the Departments' program of work during the total solar eclipse in the United States, June 8, 1918, magnetic observations were made by H. W. Fisk and C. C. Ennis at Goldendale, Washington; by L. A. Bauer at Corona, Colorado, where the elevation above sea-level is about 11,800 feet; by W. J. Peters at Lake Moraine, near Pikes Peak; by S. J. Mauchly, D. M. Wise, A. Thomson, and M. B. Smith at Lakin, Kansas; by C. W. Hewlett at Brewton, Alabama; and C. R. Duvall at Washington, D. C. In addition, special eclipse observations were made by persons associated for the occasion with the Department, viz. by G. L. Hosmer at Woburn, Massachusetts; by C. T. Knipp at Urbana, Illinois; by H. B. Wahlin at Columbia, Missouri; by J. M. Kuehne at Austin, Texas; by W. J. Raymond at Berkeley, California. Furthermore, Professor E. W. Elder and Mr. R. Sutton, of the East End High School of Denver, assisted L. A. Bauer at Corona and Mr. Robinson of Colorado College assisted Mr. Peters at Lake Moraine. The Department also received in this work the cooperation of the United States Coast and Geodetic Survey, which, besides furnishing data from its magnetic observatories, arranged for observations by S. A. Deel at Green River, Wyoming; by W. W. Merrymon at Mena, Arkansas; and by J. R. Benton at Orlando, Florida. Similarly, cooperation was received from the Canadian magnetic observatories, the Canadian magnetic survey, and from observatories in Japan, Philippines, China, and Australia. For further account of the eclipse observations, see pages 257-258 and 260-261.

After the completion of the eclipse work, the various parties proceeded to the Pikes Peak region, where magnetic observations were made at various altitudes, ranging from 6,000 to 14,000 feet above sea-level, by L. A. Bauer, C. C. Ennis, H. W. Fisk, and W. J. Peters of the Department, and by S. A. Deel and W. W. Merrymon of the United States Coast and Geodetic Survey. Atmospheric-electric observations also were made on Pikes Peak by S. J. Mauchly and M. B. Smith.

MAGNETIC OBSERVATORY WORK.

Western Australia.—In spite of vexatious delays resulting from various causes, Mr. Wallis, magnetician-in-charge, hopes to complete by the end of 1918 the observatory buildings on the site finally selected, Watheroo, which is about 120 miles north of Perth. It was mentioned

in the report of last year that the site, consisting approximately of 220 acres, was obtained by grant from the government of Western Australia, through the minister for lands and agriculture. Mr. Wallis has been assisted in his arduous task by Observer W. C. Parkinson. Every effort will be made to have the observatory in operation by January 1, 1919.

Peru.—The erection of the contemplated observatory in Peru has had to be deferred pending the completion of the one at Watheroo.

Washington.—The standardizations of the magnetic instruments have been made from time to time in the Standardizing Observatory. An interesting series of comparisons was the one carried out in conjunction with the United States Coast and Geodetic Survey by which another control was obtained upon the maintenance of standards (see page 239). The experimental studies in terrestrial magnetism, in atmospheric electricity, and on earth-currents have been continued. Photographic registrations of the atmospheric-electric potential gradient have been obtained throughout the year in the temporary structure on the deck of the laboratory. Likewise some photographic registrations of the electric conductivity have been obtained and various improvements have been made in the recording instruments, which are ultimately to be installed at our observatories in foreign countries.

RESEARCH WORK IN WASHINGTON. TERRESTRIAL MAGNETISM.

Owing to various interruptions it was not possible to complete during the year the entire manuscript for Volume IV. However, continued good progress has been made by the present limited personnel. A great variety of investigations, experimental and theoretical, relating to problems of defense and research, have been conducted by members of the investigating staff in conjunction with various Government bureaus and the National Research Council. The results of much of this investigational work can not be published at present. Some of it will have a direct bearing on our future research and observational work.

Investigations and experiments were begun with a view to reducing oscillations and deviations of the magnet in ship compasses and dip circles caused by the motions experienced under actual service conditions. Pending the construction of an oscillating platform for more elaborate experimenting, several types of swings have been used temporarily in the Standardizing Magnetic Observatory to examine the effects produced by oscillating platforms when they are constrained to move in one plane. Although important facts have been obtained by these experiments, it is yet too early for any final conclusions.

Those taking chief part in the above investigations were: L. A. Bauer, W. J. Peters, J. A. Fleming, J. P. Ault, H. W. Fisk, C. R. Duvall,

and C. C. Ennis. Abstracts of contributions to scientific societies and of articles published by them will be found on pages 259-268.

It would seem to be now definitely established, as the combined result of researches by various investigators, that the Earth's actual magnetic state at any specified time is singularly dependent upon solar conditions, and the problem of the ultimate causes is becoming increasingly complex with advancement in knowledge. The want of adequate facilities with which Nature's processes can be simulated to a certain degree, at least, by laboratory experiment, is gradually being filled since the erection of the Laboratory in 1914. Some of these laboratory experiments will require a special non-magnetic structure for successful execution with the requisite refinement, entirely apart from the non-magnetic standardizing observatory already on the laboratory site.

MAGNETISM IN GENERAL.

The hope is entertained that means will soon be provided for the new proposed structure, in which broad and fundamental investigations in magnetism, in general, may be conducted. The Department is fortunate in having secured on July 1, 1918, as the person to conduct this important experimental work, Dr. S. J. Barnett, formerly professor of physics at the Ohio State University. Dr. Barnett is well known for his successful experiments on magnetization by rotation; he has also had practical experience in terrestrial magnetism, having been a magnetic observer when the Director was in charge of the magnetic work of the United States Coast and Geodetic Survey. Since the assumption of his duties in the Department he has been engaged in the necessary preparations for the coming experimental work and in the designing of apparatus; he has also taken part in the investigations mentioned in the first paragraph of this section. He hopes to continue his experimental work on magnetization by rotation with better facilities and with such refinement that it will be possible to show conclusively whether the positive electrons contribute anything appreciable to the Ampèreian currents. The experiments on magnet-photography, of which a preliminary account was given in the annual report for 1917 (pp. 254-255), have been resumed, using more intense magnetic fields and otherwise modified conditions.

TERRESTRIAL ELECTRICITY.

The investigational work in atmospheric electricity and earth currents has been mainly conducted by the observatory division under the charge of J. A. Fleming as chief of the division and S. J. Mauchly, assistant chief, Dr. W. F. G. Swann having resigned his post at the end of 1917 to accept a professorship in physics at the University of Minnesota. Some mention of the work under this head will be found

on page 235 and on page 236 (eclipse observations). Assistance was received in this work from Messrs. D. M. Wise, M. B. Smith, and C. A. Kotterman.

With reference to the photographic records of the potential gradient and the electric conductivity of the atmosphere, it was found that some of the records obtained show strikingly the effect of the potential gradient on the recorded conductivity; this is especially true during periods of large negative potential-gradient when the recorded positive conductivity frequently became vanishingly small. It is hoped soon to make a special study of this matter and also of the relation between the atmospheric ions of ordinary mobility and those of much smaller mobilities. This latter study is held in abeyance pending reconstruction of certain parts of the apparatus in use. Some time has been devoted to consideration of various types of batteries for use with the atmospheric-electric equipment; at present batteries composed of silver-chloride cells are being tried; thus far the results appear quite favorable.

An abstract of a paper by Dr. Mauchly, on the results of his earth-current experiments, is given on pages 263-265.

A preliminary test of the special Toepfer planimeter for scaling of observatory traces was carried out and reported upon by C. A. Kotterman, laboratory assistant. It was found that while a high degree of accuracy was obtainable with the planimeter, the time required for determining mean areas by this method was excessive and would be hardly warranted in actual practice except for limited work requiring very precise measurements. It will probably, therefore, be best to arrange for scaling of the mean areas of traces obtained in the observatory work by the use of transparent glass plates with suitable area-scales etched or engraved on the under sides; this method of scaling is now used at the observatories of the United States Coast and Geodetic Survey and elsewhere.

STANDARDIZING AND INSTRUMENT WORK.

Reference to standardizations of instruments and determination of constants has been made on page 237. The amount of this work was greatly increased over that of previous years because of the return of field parties and of the *Carnegie*. Simultaneous comparisons of instruments to determine constants and to determine corrections on our adopted magnetic standards were made for 12 magnetometers, 5 dip circles, 4 earth inductors, 2 universal magnetometers, 1 sea deflector, 1 marine collimating-compass, and for the compasses of 5 dip circles.

Investigations relating to the sources of error in terrestrial-magnetic measurements and the causes for changes of instrumental constants were continued as far as time and personnel permitted. The compilations of data and the investigations of possible changes in the dis-

tribution coefficients for different instruments were continued; thus far the tentative conclusions reached in last year's report are borne out.

The standardization and calibration of magnetic and atmospheric-electric instruments on board the *Carnegie* were completed at Washington promptly after the return of the vessel. The compilation of corrections and constants necessary for the final reductions of the *Carnegie* work since the publication of Volume III of the *Researches* of the Department are under way.

An extensive equipment, including instruments, constants, instructions, miscellaneous tools and appurtenances, and forms, was made ready early in 1918 for the Amundsen Arctic Expedition, which it is expected will require about 5 years to accomplish its proposed work.

The work of the instrument shop during the year may be classified about as follows: Equipment, 13 per cent; experimental, 14 per cent; improvement of instruments, 11 per cent; repairs of instrumental equipment, 32 per cent (this latter item is rather large because practically all field instruments have been returned to the office after long periods of service and have required much overhauling and repairing); special emergency work for outside parties, 25 per cent; miscellaneous, including maintenance and stock charges, 5 per cent. During the year three special compass variometers were designed and constructed, together with their gimbal stands, also two special artificial horizons and appurtenances for use in the navigation of aeroplanes. A considerable part of the instrumental work was in connection with the study of designs for possible stabilizing devices and of improvements in instruments to eliminate oscillations and deviations, brought about by linear accelerations causing tilting of the magnetic needles in an instrument on board ship.

Considerable time was devoted to the overhauling, remaking, and modification of magnetometer 8 and dip circle 205 for use on the Amundsen Arctic Expedition. Because of the low temperatures to be encountered, all parts of these instruments, so far as possible, that are handled with the fingers during observational work were provided with celluloid caps to prevent the bare fingers from touching the metal and also to increase somewhat the diameters of the clamping and adjusting screws to facilitate handling. In connection with these improvements a dip-needle lifting and turning device was designed for the dip circle; it was feared, however, that this device, since it depended for its successful operation somewhat on the sense of touch, would not be altogether practicable for use in the Arctic, and it was therefore removed from the instrument and the program of observations was so arranged that the necessity for handling the needle and turning it on its bearing was reduced to a minimum.

The following field instruments were reconstructed during the year; magnetometers 8, 9, 13, and 16; dip circles 172, 177, 205, 206, and 222;

and one Gambey sextant. It should be noted that the overhauling was so thorough in each case as to make the instrument equivalent to a new one. Minor instrument repairs were made as necessary.

In connection with the development of the optical system of the compass variometers it was necessary to go into the subject of casting and finishing speculum metal. Instrument-maker E. K. Skonberg, foreman of the instrument shop, made a careful study of the methods of finishing speculum metal and submitted a report thereon. The difficulty in working the metal is of course largely due to its extreme brittleness, and for the work in hand this difficulty was enhanced because the mirrors were in the form of circular and conical segments with sharp edges. It was found that a lead lap loaded with a medium emery and lubricated with kerosene was best suited for the initial grinding. To obtain the mirror finish, a lap was made of pure beeswax mixed with clean rosin and covered with a very fine, clean rouge. The proper mixture depends of course upon the weather conditions at the time of use, and is roughly about one part by weight of rosin to ten parts of beeswax. The mirrors obtained show particularly good reflecting surfaces.

Instrument-maker C. Huff continued in charge of the brass foundry, which was in operation whenever necessary. Over 1,500 pounds of castings in brass, gun bronze, copper, aluminum, lead, bell metal, speculum metal, and various alloys were made. Some difficulty was experienced in obtaining satisfactory speculum-metal castings of the shapes required, but methods were developed to overcome this. The alloy found most satisfactory was the following: 65.4 per cent copper, 30.0 per cent tin, 0.6 per cent zinc, 2.0 per cent silver, and 2.0 per cent arsenic. This speculum gives a very good reflecting surface. Coke being unobtainable, it was found necessary to use anthracite coal for heating the brass-foundry furnaces. Coal was found satisfactory, but it requires greater draft than necessary with coke; a mechanical blower was therefore added to the foundry equipment.

Besides the members of the instrument shop already mentioned in the preceding paragraphs, Messrs. G. H. Jung, W. F. Steiner, and J. G. Lorz deserve mention for their excellent instrumental work during the year, while Mr. A. Smith, carpenter, has rendered valuable service, particularly in the construction of motion tables and paraphernalia for experimental work concerned with the behavior of sea instruments and in the construction of instrument cases and other improvements about the laboratory. The shop work has been carried out, as heretofore, under the direction of the observatory division (J. A. Fleming, chief; S. J. Mauchly, assistant chief). Upon the resignation of J. A. Widmer, at the end of 1917, to become experimental engineer with the Sperry Gyroscope Company, Mr. Skonberg was made foreman of the shop.

THE POLICY OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM.

By the end of the present fiscal year of the Institution, October 31, 1918, the Department of Terrestrial Magnetism will have been in existence nearly 15 years. A long enough period has thus elapsed to afford a favorable opportunity for retrospect and for determining as to how far the Department has been faithful to its trust, wherein it may have failed possibly to meet the hopes of its friends, or what justification there may be for fears that the existence of such a Department may furnish an excuse to some countries not to make adequate provision for the maintenance of their own magnetic establishments.*

At the very outset the following announcements were made concerning the policy and work of the proposed Department:†

"The general aim of the work is to investigate such problems of world-wide interest as relate to the magnetic and electric condition of the Earth and its atmosphere, not specifically the subject of inquiry of any one country, but of international concern and benefit. The prime purpose, therefore, of this Department is not to *supplant* any existing organization, but rather to *supplement*, in the most effective manner possible, the work now being done, and to enter only upon such investigations as lie beyond the power and scope of the countries and persons actively interested in terrestrial magnetism and atmospheric electricity.

"At first, principal stress will be laid upon the complete reduction, discussion, and correlation of the existing observational data and upon early publication of the results in suitable form, in order to exhibit the present state of our knowledge. In this way will be revealed the gaps to be filled, and the direction of future and supplementary investigations will be suggested. While, however, this will constitute at first the chief work of the Department, it is likewise proposed to embrace favorable opportunity for supplementing by observation the existing data, and to cooperate with others in the observing of such of the Earth's magnetic and electric phenomena as are of momentary occurrence, and the investigation of which is of great importance."

The title of the Department, as at first proposed, was "International Magnetic Bureau," which was changed by action of the Trustees of the Institution to "Department of International Research in Terrestrial Magnetism of the Carnegie Institution of Washington," when the Department was definitely established on April 1, 1904.

The project, previous to its being laid before the Institution, was submitted by L. A. Bauer to certain leading investigators for their counsel and criticism. It received the immediate support of these gentlemen, and the project was then forwarded to the Institution accompanied by letters of indorsement from the following eminent persons: General L. Bassot, then president of the Bureau of Longitudes of France; Professor W. von Bezold, the late director of the Prussian

*Such a fear is expressed in a "Preliminary Report on Terrestrial Magnetism," by Dr. Charles Chree, published in the Report of the British Association for the Advancement of Science for 1917.

†See Year Book of the Carnegie Institution of Washington for 1903, pp. 203-212, and the Journal of Terrestrial Magnetism and Atmospheric Electricity for 1904, pp. 1-8.

Meteorological Institute; Professors J. Elster and H. Geitel, the well-known authorities on atmospheric electricity; Professor E. Mascart, the late director of the Bureau Central Météorologique of France; Professor G. Neumayer, the late director of the Deutsche Seewarte at Hamburg; Professor A. Schuster, at the time director of the Physical Laboratory of Owens College, University of Manchester; and Mr. O. H. Tittmann, then superintendent of the United States Coast and Geodetic Survey. Upon the establishment of the Department, letters of good will were received from other noted men, among whom was the late Sir Arthur Rücker, then president of the International Permanent Committee on Terrestrial Magnetism and Atmospheric Electricity. Captain Ettrick W. Creak, at one time superintendent of the Compass Department of the British Admiralty, wrote a letter in 1904 favoring the taking up at once, by the Department, a magnetic survey of the North Pacific Ocean.

In 1904, Professors von Bezold, Elster and Geitel, Mascart, Rücker, and Schuster were appointed, by the Institution, members of the Advisory Council to assist the Director in determining the lines of activity of immediate importance and in adopting a definite policy with regard to existing organizations. One of the first changes made as the result of advice from members of this Council was the dropping of the word "International" in the name of the Department. Furthermore, only one of the advisers favored some connection with an international association, and even he did not think it desirable to have more than a nominal connection. Since the funds were to be supplied entirely by the Carnegie Institution of Washington, it was not possible to organize the Department in accordance with the customs governing international organizations, the funds of which are contributed by various nations in concert—for example, the International Geodetic Association, International Catalogue of Scientific Literature, International Seismological Association, etc. One of the advisers expressed strongly the opinion that it would not be advantageous for the Department to be tied up with any strictly international organization. This policy was furthermore favored by the present President of the Institution, who came to the Institution shortly after the establishment of the Department. While the basis of organization of the Department could not be international in the sense usually defined by such bodies, a review of the work and policy will show, it is believed, that at all times consideration has been paid to advice received by letter or appearing in reviews, by representatives of countries the world over.

Before undertaking, for example, the magnetic survey of the oceans, as also atmospheric-electric work, the Director, during a visit to Europe in the spring of 1905, consulted not only members of the Advisory Council but also many other persons in England, France, and Germany. The general opinion at that time appeared to be that

one of the most important tasks to be undertaken was that of the magnetic survey of the oceans, and that this was a project which would not likely be carried out in the near future unless an institution with ample funds would foster it.

In the citation given above it was stated that "at first, principal stress will be laid upon the complete reduction, discussion, and correlation of existing observational data." It was quickly found that rather than attempt to refer existing observations, the precise reliability of which could not always be gaged without very considerable labor, to a common date on the basis of more or less uncertain secular-variation data, it would be far more expeditious and certainly much more satisfactory in the end, to secure entirely new observations by uniform methods, with carefully controlled instruments, and extending over a period of about 10 to 15 years. The existing data not infrequently dated back in certain regions 50 years or more. Furthermore, when Adolf Schmidt, of Potsdam, began his series of publications, in which results of past observatory observations were being collected and reduced to some common basis, there was no need of similar work by the Department. Thus it happened that a new magnetic survey of the globe with the cooperation of existing organizations was undertaken sooner than originally contemplated. This task, in general, has been accomplished within the period set. In some regions certain details are lacking, and some countries, owing to the war, will find it difficult to supply the results of their recent work. Nevertheless sufficient has been accomplished by this time to make it worth while to construct new magnetic charts and to take up the investigation of certain fundamental problems respecting the actual constitution of the Earth's magnetic field. Such a question, for example, as that of the existence or non-existence of vertical earth-currents passing through the Earth's crust may be possible of definite solution dependent upon data acquired, on sea and land, solely by the Department.

No complaint of any kind has ever been received by the Institution, or the Department, respecting the policy followed in the conduct of the land magnetic-survey work. In no country has ever any work been undertaken by the Department without previous consultation with the interested authorities and individuals, or without ascertaining the likelihood of its being undertaken in the near future by the respective countries. In fact, to our observers have invariably been assigned the most difficult tasks. There have been some cases in which we have been the direct means of securing for an individual desirous of making a magnetic survey of his country, the necessary funds and support from his government. In one particular case it was necessary to have our observers start the survey of a certain country in order that the governmental authorities might be sufficiently convinced of the importance of such work. When official funds were provided, our observers were withdrawn.

The magnetic survey of Australia had to be undertaken by us; for, after consultation with the leading investigators and governmental authorities, there was found to be but little prospect that the Commonwealth would be able in the near future to contribute the necessary funds and to organize the necessary personnel. The funds and personnel at the disposal of the Ottawa Observatory and of the Meteorological Service of Canada not being adequate for extensive magnetic-survey work, and there being but little likelihood that before long matters would be improved, we, accordingly, made ourselves chiefly responsible for the expensive and difficult portions of the general magnetic survey of Canada. Thus were sent out the Department's canoeing expeditions in the wilds of Canada by Messrs. Ault, Edmonds, Stewart, and Wise.

Other cases might be cited showing the manner in which the Department has undertaken its work. However, a merely superficial glance over plate 1 will show that the attempt has been made not to duplicate work or "to supplant any existing organization, but rather to supplement in the most effective manner possible the work being done." It is believed that it could be proved without much difficulty that instead of the sum-total of available funds for magnetic work to existing organizations, other than the Department, having been diminished during the period 1904-1918, there has been an actual increase.

Equal care to that shown in the conduct and policy of the magnetic-survey work is being given to the selection of sites for the proposed observatories of the Department. Everyone is familiar with the very unsatisfactory distribution of the present magnetic observatories. More than three-fourths of them are in the Northern Hemisphere, chiefly in Europe, but the number in the Southern Hemisphere totals at present seven. For many years past this unsatisfactory state of matters has been pointed out again and again by leading investigators, learned academies, and international associations, but very little has been done in the way of remedy. Three years ago we made a tentative selection of sites for magnetic or cosmo-physical observatories, most of which were to be in the Southern Hemisphere. The sites were submitted to various interested persons and their advice and wishes were solicited. A small beginning towards increasing the number of magnetic observatories in the Southern Hemisphere has been made, for (as stated on pages 235-236) a magnetic observatory in Southwestern Australia will soon be put in operation by the Department.

FUNDS.

While the funds made annually available to the Department of Terrestrial Magnetism by the Trustees of the Carnegie Institution of Washington may appear large, they are not as ample in proportion to

the tasks assumed as some existing magnetic institutions have at their disposal for their more limited tasks. Hence, it has been necessary at all times to plan and execute the world-wide work of the Department with careful regard to all details and with rigid economy. The cost of such extensive expeditions as the Department has sent out, as for example, the crossing of China from east to west, the trans-Saharan expedition, the crossing of equatorial Africa from west to east, the interior expeditions in Australia and South America, the canoeing expeditions in British North America, the ocean magnetic surveys, have almost invariably been less than that estimated, sometimes by as much as 50 per cent, by government authorities or travelers familiar with the region to be traversed, or as judged by the costs of previous similar expeditions.

GRANTS.

At the beginning, the Department hoped that it would be possible to have some of its work economically and expeditiously accomplished by means of grants to individuals connected with official institutions. In all, four main grants were made. The experience, however, has not been wholly satisfactory and it has been found necessary, therefore, to discontinue making these subventions.

SPECIAL COOPERATIVE WORK.

The Department has been fortunate in the voluntary cooperation secured from institutions the world over in cases of special work. Thus a vast amount of published data have been accumulated bearing on the question of possible magnetic and electric effects during times of total solar eclipses. By arranging for a definite program, limited in its scope by the available personnel and instrumental outfits, world-embracing observational data were obtained generally with very gratifying promptness.

COMPARISONS OF INSTRUMENTS.

Equally satisfactory cooperation as that mentioned in the previous paragraph has been received by the Department from magnetic institutions the world over in the matter of intercomparisons of respective magnetic instruments. The observers of the Department have compared the instruments used by them with those used at foreign magnetic observatories or in magnetic-survey work by other organizations, so that for the first time it will be possible to reduce nearly all the observational data obtained during 1904-1918, by the Department and diverse organizations, to a common basis within an error generally less than the observational error. The aim on the part of the Department has been to make such a selection of a common standard, based on these world-embracing intercomparisons, as would amply meet the practical requirements for the purpose intended.

It is believed that the results of intercomparisons of instruments already published by the Department amply show that the purposes have been accomplished. While for obvious reasons it was necessary for the Department to make a provisional choice itself of the magnetic standards to which the existing observational data are to be reduced in the preparation of its own world magnetic charts, that choice was based upon a critical study of the available data from institutions in all parts of the world. When others have adopted our choice, it has been as the result of their own judgment on the basis of the evidence presented and without any solicitation on our part. By our methods we have been able to disclose important instrumental errors at various observatories.

The present time is a favorable one for making any required changes, if any mistakes have been made in the conduct of the past work and with regard to the policy followed by the Department. The general magnetic-survey work has reached its first stage of completion and we are preparing now to take up some of the other lines of research outlined in the original project and announced in various past annual reports. Both the President of the Institution and the Director of the Department will be pleased to receive at any time suggestions, as well as constructive criticisms, from those interested in the advancement of our knowledge of the physics of the Earth.

DETAILS OF OBSERVATIONAL WORK.

OCEAN WORK.

At the beginning of the fiscal year preparations were being made to start the *Carnegie* on her homeward cruise from Buenos Aires to an Atlantic port, by way of Cape Horn, the Pacific Ocean, and the Panama Canal. This cruise, designated "Cruise V," began at Buenos Aires on December 4, 1917, the *Carnegie* having been detained at this port for over 9 months on account of the war.

The passage around Cape Horn to Talcahuano, Chile, was made in the short time of 38 days, arrival at the latter port occurring on January 11, 1918. Although the usual stormy weather and heavy seas were encountered off Cape Horn, the winds usually drew from favorable directions. The daily average for the 38 days at sea was 102 nautical miles, and the usual daily program of magnetic and other work was carried out without serious interruption.

After a stay of 12 days at Talcahuano, during which time the C. I. W. magnetic stations at Coronel and at Concepcion were reoccupied, the *Carnegie* sailed again on January 23, 1918, for Callao, Peru. After making a large detour to the westward in order to fill in unsurveyed areas, the vessel arrived at Callao on February 22, 1918, having made a highly successful trip of 30 days.

During the stay of over one month at Callao, a complete program of intercomparisons of instruments was carried out at a former C. I. W. station at Lima. On March 29, 1918, the vessel set sail for Balboa, Canal Zone, arriving there on April 24, 1918, after making another detour to the westward to cover unsurveyed regions. On May 2, 1918, the *Carnegie* for the second time passed through the Panama Canal, this time from the Pacific to the Atlantic.

After a stay of 9 days at Cristobal, during which an intercomparison of instruments was again made, the *Carnegie* started out on the final part of her journey homeward on May 11, 1918. Owing to light winds and adverse currents some difficulty was experienced in clearing the coast of Panama. Conditions were also unfavorable for making the route called for to the eastward through the Caribbean Sea, so that it was necessary to set the course westward and return through the Gulf of Mexico and the Straits of Florida. On June 4, 1918, the vessel arrived at Newport News.

On June 8, 1918, the *Carnegie* left Newport News for Washington, where she arrived on June 10, 1918, after spending a day in swinging-ship observations in Chesapeake Bay. Declination observations were also made in the bay and in the Potomac River. The trip from Old Point Comfort to Washington was made entirely under the vessel's own power. Thus after an absence of nearly three and one-half years the *Carnegie* was once more in a home port on the Atlantic coast.

During this Cruise V, the *Carnegie* traveled over 13,786 miles of ocean, and the daily average for the 122 days at sea was 113 miles. Tracks of former cruises by this same vessel were crossed 10 times and *Galilee* tracks were crossed 3 times, thus furnishing further valuable information regarding secular variation.

As usual, observations for magnetic intensity and inclination at sea were made daily, regardless of sea and weather. Magnetic-declination results were obtained every day but four, which were too cloudy for these observations.

The ship's personnel during November 1917 to the close of Cruise V in June 1918 was as follows: Dr. H. M. W. Edmonds, magnetician and surgeon and in command of vessel; A. D. Power, magnetician and second in command; B. Jones, L. L. Tanguy, and J. M. McFadden, observers; W. E. Scott, stenographer-recorder; A. Beech, first watch officer; M. G. R. Savary, engineer; L. Larsen and A. Erickson, second and third watch officers, respectively; C. Heckendorn, mechanic; 8 seamen, 2 cooks, and 2 cabin boys; the complete personnel at any one time thus consisted of 23 persons.

The atmospheric-electric observations were continued throughout the cruise.

Table 2 contains the preliminary results of ocean magnetic observations on the *Carnegie* for Cruise V from Buenos Aires to Washington, D. C., December 1917 to June 1918.

TABLE 2.—*Preliminary results of ocean magnetic observations on the Carnegie from Buenos Aires to Washington, D. C., December 1917 to June 1918.*¹

Observers: H. M. W. Edmonds, commanding the *Carnegie*; A. D. Power, B. Jones, L. L. Tanguy, J. M. McFadden, and W. E. Scott.

Date.	Lat.	Long. east of Green- wich.	Carnegie values.			Chart differences. ²					
						Decl'n and Incl'n.			Hor. Int.		
			Decl'n.	Incl'n.	Hor. Int.	Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1917	° /	° /	°	°	c.g.s.	°	°	°	*	*	*
Dec. 6	35 17 S	303 19	3.7 E	.....	...	0.1 E	0.1 E	0.3 E	....	....	....
6	35 17 S	303 34	3.5 E	.....	...	0.2 E	0.1 E	0.4 E	....	....	....
7	35 43 S	304 05	3.2 E	.....	...	0.2 E	0.3 E	0.2 E	....	....	....
7	35 53 S	304 10	.....	29.6 S	.244	0.3 N	0.6 S	.....	— 7	— 6	—12
7	36 15 S	304 21	3.0 E	.....	...	0.0	0.1W	0.0	....	....	....
8	37 31 S	304 59	2.9 E	.....	...	0.1W	0.2W	0.0	....	....	....
8	38 02 S	305 03	.....	31.5 S	.244	0.8 N	0.3 S	.....	— 8	— 8	—13
8	38 20 S	305 04	3.1 E	.....	...	0.2W	0.1W	0.0	....	....	....
9	39 07 S	304 45	3.6 E	.....	...	0.3W	0.3W	0.1W	....	....	....
9	39 15 S	304 53	.....	32.9 S	.245	0.8 N	0.1 S	.....	— 8	— 8	—13
9	39 04 S	304 38	3.7 E	.....	...	0.3W	0.1W	0.4W	....	....	....
10	38 53 S	303 33	4.5 E	.....	...	0.3W	0.1 E	0.2W	....	....	....
10	39 00 S	302 57	.....	32.7 S	.248	1.0 N	0.3 N	.....	— 7	— 7	—12
10	39 01 S	302 55	5.2 E	.....	...	0.2W	0.3 E	0.1W	....	....	....
11	39 48 S	302 32	5.6 E	.....	...	0.4W	0.0	0.3W	....	....	....
11	40 06 S	302 21	.....	34.1 S	.248	0.9 N	0.3 N	.....	— 8	— 9	—13
11	40 18 S	302 10	6.2 E	.....	...	0.3W	0.5 E	0.1W	....	....	....
12	41 18 S	301 13	7.3 E	.....	...	0.1W	0.2 E	0.1 E	....	....	....
12	42 15 S	300 17	.....	36.9 S	.252	1.0 N	0.3 N	.....	— 9	—10	—14
12	42 42 S	299 35	8.9 E	.....	...	0.0	0.2 E	0.0	....	....	....
13	43 27 S	298 53	9.6 E	.....	...	0.0	0.3 E	0.0	....	....	....
13	43 22 S	299 04	.....	37.8 S	.256	1.6 N	1.0 N	.....	— 8	— 9	—12
13	43 16 S	298 58	9.6 E	.....	...	0.1 E	0.4 E	0.2 E	....	....	....
14	43 04 S	298 44	9.6 E	.....	...	0.0	0.2 E	0.0	....	....	....
14	43 04 S	298 54	.....	37.6 S	.256	1.7 N	1.1 N	.....	— 8	— 8	—12
14	43 00 S	298 54	9.6 E	.....	...	0.1 E	0.4 E	0.1 E	....	....	....
15	43 42 S	298 12	10.2 E	.....	...	0.0	0.3 E	0.1 E	....	....	....
15	44 54 S	297 15	.....	40.0 S	.259	1.1 N	1.0 N	.....	—10	— 9	—12
15	45 31 S	296 47	11.8 E	.....	...	0.1 E	0.3 E	0.4 E	....	....	....
16	46 50 S	296 49	12.0 E	.....	...	0.1W	0.4 E	0.2 E	....	....	....
16	47 42 S	296 55	.....	42.8 S	.261	1.0 N	0.9 N	.....	—11	—11	—12
16	47 55 S	296 51	12.7 E	.....	...	0.3 E	0.8 E	0.6 E	....	....	....
17	49 00 S	296 52	12.6 E	.....	...	0.2W	0.4 E	0.2 E	....	....	....
17	50 06 S	297 32	.....	45.0 S	.265	0.9 N	1.0 N	.....	— 7	—10	— 8
17	50 30 S	297 45	12.5 E	.....	...	0.2W	0.3 E	0.1 E	....	....	....
18	51 04 S	297 51	12.4 E	.....	...	0.3W	0.0	0.1W	....	....	....
18	51 38 S	297 56	.....	46.8 S	.266	0.4 N	0.5 N	.....	—11	—11	— 7
18	51 56 S	298 13	12.4 E	.....	...	0.3W	0.0	0.1W	....	....	....
19	52 45 S	299 19	11.9 E	.....	...	0.4W	0.2W	0.1W	....	....	....
19	53 15 S	300 17	.....	47.7 S	.263	0.5 N	0.8 N	.....	— 8	—13	— 8
19	53 25 S	300 52	11.2 E	.....	...	0.3W	0.1W	0.1 E	....	....	....
20	53 14 S	300 33	11.0 E	.....	...	0.6W	0.5W	0.3W	....	....	....
20	53 08 S	300 12	.....	47.4 S	.264	0.7 N	1.0 N	.....	— 7	—12	— 7
20	53 09 S	299 38	12.0 E	.....	...	0.2W	0.0	0.1 E	....	....	....

¹For previous table, see Annual Report for 1917.

²Charts used until April 24, 1918: U. S. Hydrographic Office Chart No. 2406 for 1915 and No. 1701 for 1900; British Admiralty Charts No. 2598 for 1912, Nos. 3598 and 3603 for 1907; Reichs-Marine-Amt Charts Tit. XIV, No. 2 for 1910, Tit. XIV, Nos. 2a and 2b for 1905. The chart differences are obtained by subtracting corrected chart values, derived as explained in previous sentence, from the observed *Carnegie* values. The letter *E* signifies that the chart value for east declination is smaller, or the chart value for west declination larger, than the *Carnegie* value; *W* signifies the reverse. The letter *N* signifies that the derived chart value for northerly inclination is smaller, or for southerly inclination larger, than the *Carnegie* value; *S* signifies the reverse. The plus sign signifies that the derived chart value for horizontal intensity is smaller than the *Carnegie* value, the minus sign meaning, of course, the reverse.

*Units of third decimal c. g. s.

TABLE 2.—*Preliminary results of ocean magnetic observations on the Carnegie from Buenos Aires to Washington, D. C., December 1917 to June 1918—Continued.*

Date.	Lat.	Long. east of Green- wich.	Carnegie values.			Chart differences.					
						Decl'n and Incl'n.			Hor. Int.		
			Decl'n.	Incl'n.	Hor. Int.	Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1917	° /	° /	°	°	c.g.s.	°	°	°	*	*	*
Dec. 21	53 30 S	299 38	11.9 E	.....	...	0.4W	0.2W	0.2W	....	....	....
21	53 34 S	299 30	.....	48.3 S	.263	0.3 N	0.8 N	.....	- 8	-14	- 8
21	53 45 S	299 05	12.6 E	.....	...	0.1W	0.2 E	0.2 E	....	....	....
22	55 11 S	296 45	.....	50.1 S	.266	0.7 N	0.9 N	.....	- 7	-14	- 7
23	55 56 S	295 21	15.3 E	.....	...	0.3W	0.1 E	0.2W	....	....	....
23	56 13 S	295 46	.....	51.3 S	.266	0.7 N	1.0 N	.....	- 7	-14	- 7
23	56 18 S	295 50	15.3 E	.....	...	0.2W	0.2 E	0.1W	....	....	....
24	56 54 S	294 49	16.3 E	.....	...	0.1 E	0.3 E	0.1 E	....	....	....
24	57 41 S	291 46	.....	53.7 S	.266	0.7 N	0.6 N	.....	- 7	-12	- 8
24	58 00 S	290 59	18.5 E	.....	...	0.2W	0.2W	0.5W	....	....	....
25	58 29 S	289 16	20.4 E	.....	...	0.5 E	0.7 E	0.3 E	....	....	....
25	58 56 S	288 06	.....	55.3 S	.264	1.4 N	0.9 N	.....	-10	- 8	-10
25	58 57 S	287 46	20.8 E	.....	...	0.1W	0.0	0.3W	....	....	....
26	58 33 S	286 14	22.1 E	.....	...	0.6 E	0.6 E	0.3 E	....	....	....
26	58 11 S	285 46	.....	55.4 S	.264	1.3 N	0.8 N	.....	-11	- 8	-11
27	57 32 S	286 28	21.6 E	.....	...	0.6 E	0.6 E	0.4 E	....	....	....
27	57 44 S	286 16	.....	54.7 S	.266	1.3 N	1.0 N	.....	- 9	- 8	-10
27	57 52 S	285 55	21.6 E	.....	...	0.1 E	0.1 E	0.2W	....	....	....
28	58 14 S	285 22	22.1 E	.....	...	0.3 E	0.3 E	0.0	....	....	....
28	58 38 S	284 39	.....	56.0 S	.267	1.4 N	0.8 N	.....	- 8	- 4	- 8
29	59 08 S	284 21	22.5 E	.....	...	0.2W	0.3W	0.6W	....	....	....
29	59 08 S	284 13	.....	56.4 S	.265	1.7 N	1.0 N	.....	- 9	- 4	- 9
29	59 06 S	283 40	23.1 E	.....	...	0.1 E	0.1W	0.3W	....	....	....
30	58 45 S	282 04	23.6 E	.....	...	0.1W	0.2W	0.6W	....	....	....
30	58 25 S	280 41	.....	56.9 S	.264	1.7 N	0.7 N	.....	-12	- 4	-10
30	58 17 S	280 30	24.3 E	.....	...	0.0	0.1W	0.4W	....	....	....
31	55 30 S	279 37	.....	54.6 S	.271	1.2 N	1.3 N	.....	- 7	- 1	- 7
1918											
Jan. 1	53 06 S	279 44	23.2 E	.....	...	0.6 E	0.4 E	0.5 E	....	....	....
1	52 12 S	280 09	.....	51.8 S	.272	0.1 N	1.2 N	.....	- 8	- 5	- 9
1	51 44 S	280 24	22.2 E	.....	...	0.2 E	0.2 E	0.3 E	....	....	....
2	52 15 S	278 54	.....	52.2 S	.271	0.1 N	1.2 N	.....	- 9	- 5	- 9
2	52 23 S	278 49	23.2 E	.....	...	0.4 E	0.2 E	0.3 E	....	....	....
3	52 27 S	278 56	23.1 E	.....	...	0.3 E	0.3 E	0.2 E	....	....	....
3	51 50 S	279 14	.....	51.6 S	.272	0.1 N	1.4 N	.....	- 8	- 4	- 9
3	51 35 S	279 24	22.4 E	.....	...	0.2 E	0.1 E	0.1 E	....	....	....
4	50 45 S	279 52	22.6 E	.....	...	0.8 E	0.7 E	0.8 E	....	....	....
4	50 17 S	279 53	.....	50.0 S	.273	0.3 S	1.6 N	.....	- 7	- 6	- 8
4	49 55 S	279 49	21.6 E	.....	...	0.0	0.0	0.1 E	....	....	....
5	48 29 S	279 34	22.0 E	.....	...	0.8 E	0.8 E	0.8 E	....	....	....
5	47 15 S	279 23	.....	47.7 S	.273	1.1 S	1.7 N	.....	- 7	- 8	- 9
5	46 48 S	279 26	21.5 E	.....	...	0.7 E	0.8 E	0.7 E	....	....	....
6	45 18 S	280 04	20.3 E	.....	...	0.2 E	0.2 E	0.1 E	....	....	....
6	44 26 S	280 28	.....	44.9 S	.273	1.3 S	1.9 N	.....	- 5	-10	-10
7	43 00 S	281 16	19.4 E	.....	...	0.3 E	0.5 E	0.2 E	....	....	....
7	42 43 S	281 26	.....	42.8 S	.272	0.8 S	2.0 N	.....	- 5	-10	-10
7	42 37 S	281 31	19.7 E	.....	...	0.7 E	1.2 E	0.6 E	....	....	....
8	41 57 S	281 59	18.6 E	.....	...	0.0	0.4 E	0.2W	....	....	....
8	41 22 S	282 24	.....	41.4 S	.271	0.8 S	1.8 N	.....	- 4	-10	-11
8	41 05 S	282 36	18.5 E	.....	...	0.4 E	0.8 E	0.2 E	....	....	....
9	39 09 S	283 35	.....	38.8 S	.268	0.8 S	1.8 N	.....	- 5	-10	-13
9	38 57 S	283 44	17.5 E	.....	...	0.4 E	0.9 E	0.3W	....	....	....
10	37 21 S	285 28	15.9 E	.....	...	0.0	0.4 E	0.5W	....	....	....
10	36 45 S	286 28	.....	35.1 S	.265	0.5 S	1.7 N	.....	- 5	- 7	-13
10	36 34 S	286 44	15.3 E	.....	...	0.3 E	0.5 E	0.1W	....	....	....

*Units of third decimal c. g. s.

TABLE 2.—Preliminary results of ocean magnetic observations on the *Carnegie* from Buenos Aires to Washington, D. C., December 1917 to June 1918—Continued.

Date.	Lat.	Long. east of Green- wich.	Carnegie values.			Chart differences.					
						Decl'n and Incl'n.			Hor. Int.		
			Decl'n.	Incl'n.	Hor. Int.	Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1918	° /	° /	°	°	c.g.s.	°	°	°	*	*	*
Jan. 23	36 23 S	286 49	.....	34.5 S	.265	0.3 S	1.8 N	.....	- 4	- 6	-12
23	36 09 S	286 41	15.1 E	.....	...	0.2 E	0.9 E	0.2W	.....	.....	.....
24	35 33 S	286 13	14.9 E	.....	...	0.0	0.6 E	0.4W	.....	.....	.....
24	35 30 S	286 11	15.0 E	.....	...	0.1 E	0.7 E	0.3W	.....	.....	.....
24	35 11 S	285 57	.....	33.6 S	.268	0.2 S	1.8 N	.....	- 1	- 4	-10
24	34 56 S	285 47	15.1 E	.....	...	0.2 E	0.8 E	0.0	.....	.....	.....
25	33 45 S	285 10	14.6 E	.....	...	0.1W	0.3 E	0.4W	.....	.....	.....
25	32 49 S	284 46	.....	31.6 S	.267	0.5 S	1.4 N	.....	0	- 5	-12
25	32 34 S	284 38	14.9 E	.....	...	0.4 E	0.8 E	0.2 E	.....	.....	.....
26	31 30 S	284 08	14.6 E	.....	...	0.3 E	0.5 E	0.0	.....	.....	.....
26	31 15 S	284 05	.....	30.0 S	.268	0.2 S	2.0 N	.....	0	- 5	-12
26	31 04 S	283 56	14.7 E	.....	...	0.4 E	0.6 E	0.1 E	.....	.....	.....
27	30 48 S	283 40	14.6 E	.....	...	0.3 E	0.4 E	0.0	.....	.....	.....
27	30 47 S	283 31	.....	29.6 S	.270	0.6 S	1.7 N	.....	+ 2	- 4	-10
27	30 30 S	283 15	14.9 E	.....	...	0.6 E	0.7 E	0.1 E	.....	.....	.....
28	29 28 S	282 09	14.7 E	.....	...	0.4 E	0.4 E	0.2W	.....	.....	.....
28	28 54 S	281 21	.....	28.4 S	.275	1.1 S	2.0 N	.....	+ 4	- 3	- 8
28	28 40 S	280 59	14.6 E	.....	...	0.2 E	0.2 E	0.3W	.....	.....	.....
28	28 34 S	280 50	14.8 E	.....	...	0.4 E	0.4 E	0.1W	.....	.....	.....
29	27 36 S	279 14	14.4 E	.....	...	0.0	0.2W	0.5W	.....	.....	.....
29	27 24 S	278 33	.....	28.4 S	.276	2.4 S	1.6 N	.....	0	- 7	-10
29	27 17 S	278 08	15.0 E	.....	...	0.3 E	0.2 E	0.0	.....	.....	.....
29	27 16 S	278 04	14.9 E	.....	...	0.2 E	0.1 E	0.1W	.....	.....	.....
30	27 52 S	276 08	15.3 E	.....	...	0.0	0.3W	0.4W	.....	.....	.....
30	28 18 S	275 21	.....	30.8 S	.280	2.9 S	1.6 N	.....	+ 2	- 5	- 7
30	28 34 S	274 59	15.4 E	.....	...	0.4W	0.7W	0.7W	.....	.....	.....
31	29 24 S	273 31	16.4 E	.....	...	0.1 E	0.2W	0.2W	.....	.....	.....
31	29 47 S	272 51	.....	33.8 S	.279	3.7 S	1.9 N	.....	- 1	- 8	- 9
31	30 06 S	272 32	16.6 E	.....	...	0.0	0.5W	0.4W	.....	.....	.....
Feb. 1	31 05 S	271 44	16.9 E	.....	...	0.2W	0.8W	0.7W	.....	.....	.....
1	31 41 S	271 06	.....	36.7 S	.280	4.1 S	2.0 N	.....	- 2	- 6	- 7
1	31 59 S	270 45	17.2 E	.....	...	0.3W	1.0W	0.9W	.....	.....	.....
2	32 44 S	269 30	17.8 E	.....	...	0.0	0.8W	0.5W	.....	.....	.....
2	33 23 S	269 06	.....	39.5 S	.280	4.8 S	1.8 N	.....	- 3	- 5	- 6
2	33 55 S	268 49	18.5 E	.....	...	0.2 E	0.6W	0.3W	.....	.....	.....
3	35 07 S	268 10	18.8 E	.....	...	0.0	0.9W	0.5W	.....	.....	.....
3	35 42 S	268 12	.....	42.2 S	.277	4.8 S	2.2 N	.....	- 7	- 6	- 7
4	36 52 S	268 25	19.4 E	.....	...	0.2W	0.9W	0.8W	.....	.....	.....
4	36 56 S	268 51	.....	43.4 S	.276	5.0 S	2.0 N	.....	- 7	- 6	- 7
4	36 58 S	268 58	19.8 E	.....	...	0.2 E	0.4W	0.4W	.....	.....	.....
5	36 57 S	269 54	20.0 E	.....	...	0.5 E	0.1W	0.2W	.....	.....	.....
5	36 55 S	270 20	.....	42.5 S	.277	4.3 S	2.1 N	.....	- 5	- 6	- 7
5	36 54 S	270 30	19.7 E	.....	...	0.3 E	0.2W	0.5W	.....	.....	.....
6	36 57 S	271 31	20.0 E	.....	...	0.7 E	0.2 E	0.1W	.....	.....	.....
6	36 58 S	272 25	.....	41.5 S	.276	3.7 S	2.3 N	.....	- 4	- 8	- 9
6	36 58 S	272 47	19.3 E	.....	...	0.1 E	0.0	0.6W	.....	.....	.....
7	36 58 S	274 11	19.2 E	.....	...	0.2 E	0.2 E	0.4W	.....	.....	.....
7	36 57 S	275 28	.....	40.2 S	.274	3.0 S	2.0 N	.....	- 4	-10	-11
7	36 56 S	275 55	18.9 E	.....	...	0.2 E	0.3 E	0.2W	.....	.....	.....
7	36 56 S	276 02	19.0 E	.....	...	0.3 E	0.5 E	0.1W	.....	.....	.....
8	36 29 S	277 42	18.3 E	.....	...	0.2 E	0.6 E	0.3W	.....	.....	.....
8	35 54 S	278 43	.....	37.6 S	.272	2.1 S	2.0 N	.....	- 3	- 8	-12

*Units of third decimal c. g. s.

TABLE 2.—*Preliminary results of ocean magnetic observations on the Carnegie from Buenos Aires to Washington, D. C., December 1917 to June 1918—Continued.*

Date.	Lat.	Long. east of Green- wich.	Carnegie values.			Chart differences.					
						Decl'n and Incl'n.			Hor. Int.		
			Decl'n.	Incl'n.	Hor. Int.	Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1918	° ' "	° ' "	°	°	<i>c.g.s.</i>	°	°	°	*	*	*
Feb. 8	35 38 S	279 02	17.5 E	.....	...	0.1 E	0.5 E	0.7W	....	....	....
9	34 41 S	278 56	17.5 E	.....	...	0.4 E	0.8 E	0.5W	....	....	....
9	33 59 S	278 42	.....	35.6 S	.272	2.2 S	1.6N	.....	— 2	— 8	—13
10	32 27 S	278 34	16.4 E	.....	...	0.1W	0.3 E	0.7W	....	....	....
10	31 49 S	278 36	.....	33.0 S	.274	2.0 S	2.1N	.....	+ 1	— 7	—11
10	31 36 S	278 36	16.4 E	.....	...	0.2 E	0.5 E	0.3W	....	....	....
11	30 41 S	278 27	16.1 E	.....	...	0.2 E	0.3 E	0.2W	....	....	....
11	30 06 S	278 21	.....	31.3 S	.275	2.2 S	1.9N	.....	+ 1	— 6	—10
11	30 00 S	278 18	15.9 E	.....	...	0.3 E	0.2 E	0.2W	....	....	....
11	29 55 S	278 19	16.0 E	.....	...	0.4 E	0.3 E	0.1W	....	....	....
11	29 51 S	278 22	16.0 E	.....	...	0.4 E	0.4 E	0.0	....	....	....
12	28 18 S	278 11	15.1 E	.....	...	0.1 E	0.0	0.3W	....	....	....
12	27 51 S	278 09	.....	28.8 S	.276	2.4 S	1.9N	.....	+ 1	— 7	—10
12	27 32 S	278 08	15.0 E	.....	...	0.3 E	0.0	0.1W	....	....	....
13	26 09 S	278 06	14.3 E	.....	...	0.2 E	0.3W	0.3W	....	....	....
13	25 27 S	278 14	.....	25.7 S	.279	2.1 S	2.1N	.....	+ 2	— 6	— 8
13	25 15 S	278 15	14.0 E	.....	...	0.3 E	0.2W	0.2W	....	....	....
14	24 96 S	278 29	13.8 E	.....	...	0.6 E	0.1W	0.0	....	....	....
14	23 53 S	278 32	.....	23.1 S	.281	1.8 S	2.4N	.....	+ 2	— 5	— 7
14	23 46 S	278 35	13.7 E	.....	...	0.7 E	0.0	0.1 E	....	....	....
15	22 41 S	278 57	12.8 E	.....	...	0.3 E	0.5W	0.4W	....	....	....
15	22 20 S	279 01	.....	20.7 S	.284	1.6 S	2.5N	.....	+ 4	— 4	— 5
15	22 08 S	279 09	13.0 E	.....	...	0.8 E	0.0	0.0	....	....	....
16	21 02 S	279 44	12.0 E	.....	...	0.3 E	0.5W	0.5W	....	....	....
16	20 47 S	279 50	.....	17.7 S	.286	1.3 S	3.3N	.....	+ 4	— 3	— 5
17	19 51 S	280 28	12.0 E	.....	...	0.8 E	0.1 E	0.1 E	....	....	....
17	19 36 S	280 40	.....	15.2 S	.287	0.3 S	3.3N	.....	+ 4	— 4	— 5
17	19 25 S	280 50	11.3 E	.....	...	0.3 E	0.4W	0.4W	....	....	....
18	18 35 S	281 32	11.0 E	.....	...	0.4 E	0.3W	0.4W	....	....	....
18	18 07 S	281 40	.....	12.1 S	.291	0.1N	3.7N	.....	+ 6	— 1	— 2
18	17 53 S	281 43	11.0 E	.....	...	0.6 E	0.0	0.1W	....	....	....
19	16 48 S	281 50	10.8 E	.....	...	0.7 E	0.1 E	0.1 E	....	....	....
19	16 16 S	281 53	.....	8.7 S	.294	0.8N	3.7N	.....	+ 6	— 2	— 2
19	16 04 S	281 55	10.2 E	.....	...	0.3 E	0.2W	0.3W	....	....	....
20	14 48 S	282 07	9.9 E	.....	...	0.4 E	0.1W	0.0	....	....	....
20	14 09 S	282 10	.....	5.2 S	.296	1.1N	3.8N	.....	+ 4	— 4	— 4
20	14 01 S	282 11	9.6 E	.....	...	0.4 E	0.0	0.0	....	....	....
21	13 34 S	282 22	9.6 E	.....	...	0.5 E	0.2 E	0.2 E	....	....	....
21	13 05 S	282 38	.....	2.8 S	.298	1.7N	3.9N	.....	+ 4	— 3	— 4
21	12 57 S	282 38	9.2 E	.....	...	0.4 E	0.1 E	0.0	....	....	....
22	12 17 S	282 36	.....	1.3 S	.299	1.9N	4.6N	.....	+ 3	— 5	— 5
Mar. 29	11 53 S	282 32	.....	0.4 S	.299	2.5N	4.6N	.....	+ 2	— 5	— 6
29	11 42 S	282 19	8.6 E	.....	...	0.0	0.8W	0.2W	....	....	....
30	11 06 S	281 41	8.8 E	.....	...	0.1 E	0.6W	0.1 E	....	....	....
30	10 56 S	281 19	.....	0.3N	.303	1.6N	4.4N	.....	+ 2	— 5	— 7
30	10 49 S	281 06	9.0 E	.....	...	0.2 E	0.6W	0.3 E	....	....	....
31	10 14 S	280 02	9.0 E	.....	...	0.1 E	0.6W	0.2 E	....	....	....
31	9 58 S	279 12	.....	1.3N	.309	2.3N	4.6N	.....	+ 4	— 5	— 7
31	9 57 S	278 52	9.2 E	.....	...	0.0	0.5W	0.0	....	....	....
Apr. 1	10 01 S	277 43	9.3 E	.....	...	0.1W	0.7W	0.1W	....	....	....
1	10 19 S	277 01	.....	0.5 S	.310	1.3N	4.3N	.....	+ 3	— 6	— 8
1	10 25 S	276 45	9.9 E	.....	...	0.2 E	0.3W	0.2 E	....	....	....

*Units of third decimal c. g. s.

TABLE 2.—Preliminary results of ocean magnetic observations on the Carnegie from Buenos Aires to Washington, D. C., December 1917 to June 1918—Continued.

Date.	Lat.	Long. east of Green- wich.	Carnegie values.			Chart differences.					
						Decl'n and Incl'n.			Hor. Int.		
			Decl'n.	Incl'n.	Hor. Int.	Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1918	° ' "	° ' "	°	°	c.g.s.	°	°	°	*	*	*
Apr. 2	11 09 S	275 26	10.2 E	.....	...	0.2 E	0.5W	0.1 E	....	....	....
2	11 28 S	274 50	.....	3.8 S	.310	0.1 S	3.7 N	....	+ 3	- 6	- 8
2	11 32 S	274 41	10.3 E	.....	...	0.1 E	0.8W	0.0	....	....	....
3	12 07 S	273 46	10.6 E	.....	...	0.2 E	0.9W	0.1 E	....	....	....
3	12 10 S	273 42	10.6 E	.....	...	0.2 E	0.9W	0.1 E	....	....	....
3	12 33 S	273 11	.....	6.6 S	.310	1.6 S	4.0 N	....	+ 4	- 5	- 8
3	12 43 S	272 59	10.8 E	.....	...	0.2 E	0.9W	0.1 E	....	....	....
4	13 47 S	271 38	11.2 E	.....	...	0.2 E	1.1W	0.2 E	....	....	....
4	14 23 S	270 50	.....	11.1 S	.306	3.1 S	3.5 N	....	+ 2	- 8	-10
5	15 38 S	269 18	11.8 E	.....	...	0.2 E	1.1W	0.3 E	....	....	....
5	16 13 S	268 34	.....	15.7 S	.305	4.7 S	2.5 N	....	+ 2	- 6	- 8
5	16 16 S	268 30	12.2 E	.....	...	0.4 E	1.3W	0.4 E	....	....	....
6	16 13 S	266 53	11.9 E	.....	...	0.1 E	1.6W	0.2 E	....	....	....
6	16 05 S	266 05	.....	16.5 S	.306	5.0 S	2.7 N	....	0	- 8	-10
6	15 59 S	265 45	11.8 E	.....	...	0.0	1.6W	0.1 E	....	....	....
7	15 36 S	263 38	11.4 E	.....	...	0.3W	1.8W	0.1W	....	....	....
7	15 25 S	263 22	.....	16.6 S	.310	5.9 S	2.2 N	....	0	- 8	-10
7	15 02 S	263 19	11.8 E	.....	...	0.3 E	1.1W	0.5 E	....	....	....
8	14 02 S	264 04	11.4 E	.....	...	0.1 E	1.2W	0.3 E	....	....	....
8	13 32 S	264 20	.....	12.8 S	.312	5.1 S	2.6 N	....	- 2	-10	-12
8	13 18 S	264 30	11.6 E	.....	...	0.5 E	0.8W	0.6 E	....	....	....
9	12 25 S	264 52	11.1 E	.....	...	0.2 E	1.0W	0.4 E	....	....	....
9	11 59 S	265 04	.....	9.4 S	.316	3.8 S	3.1 N	....	- 1	- 9	-10
9	11 48 S	265 10	11.3 E	.....	...	0.5 E	0.6W	0.7 E	....	....	....
10	10 53 S	265 45	10.7 E	.....	...	0.1 E	0.9W	0.3 E	....	....	....
10	10 28 S	266 06	.....	6.4 S	.318	3.2 S	3.5 N	....	- 1	- 9	-11
10	10 16 S	266 14	10.9 E	.....	...	0.5 E	0.5W	0.6 E	....	....	....
11	9 14 S	267 00	10.6 E	.....	...	0.4 E	0.4W	0.5 E	....	....	....
11	9 08 S	267 05	10.7 E	.....	...	0.5 E	0.2W	0.7 E	....	....	....
11	8 36 S	267 33	.....	2.0 S	.321	1.4 S	3.7 N	....	- 1	- 9	-11
11	8 24 S	267 44	10.6 E	.....	...	0.6 E	0.2W	0.6 E	....	....	....
12	7 43 S	268 30	10.0 E	.....	...	0.2 E	0.5W	0.1 E	....	....	....
12	7 21 S	268 53	.....	1.0 N	.322	0.0	3.8 N	....	0	- 9	-12
12	7 13 S	269 00	10.3 E	.....	...	0.6 E	0.0	0.4 E	....	....	....
13	6 31 S	269 47	9.7 E	.....	...	0.1 E	0.3W	0.0	....	....	....
13	6 17 S	270 07	.....	3.9 N	.324	0.7 N	3.9 N	....	+ 1	- 7	-11
13	6 14 S	270 12	9.9 E	.....	...	0.4 E	0.1W	0.2 E	....	....	....
14	5 38 S	271 28	9.7 E	.....	...	0.4 E	0.1W	0.2 E	....	....	....
14	5 08 S	272 14	.....	7.1 N	.323	1.3 N	4.3 N	....	0	- 8	-12
14	5 00 S	272 22	9.3 E	.....	...	0.1 E	0.1W	0.0	....	....	....
14	4 52 S	272 31	9.3 E	.....	...	0.1 E	0.1W	0.0	....	....	....
15	3 54 S	273 33	9.0 E	.....	...	0.1 E	0.1 E	0.1W	....	....	....
15	3 25 S	273 42	.....	11.0 N	.324	2.2 N	4.6 N	....	- 2	- 8	-13
15	3 12 S	273 45	8.7 E	.....	...	0.0	0.0	0.2W	....	....	....
16	2 22 S	274 14	8.5 E	.....	...	0.1 E	0.1 E	0.0	....	....	....
16	1 57 S	274 32	.....	14.5 N	.325	3.3 N	5.4 N	....	- 3	- 7	-14
16	1 49 S	274 36	8.3 E	.....	...	0.1 E	0.1 E	0.0	....	....	....
17	1 27 S	275 04	8.2 E	.....	...	0.2 E	0.2 E	0.1 E	....	....	....
17	1 04 S	275 27	.....	16.5 N	.326	3.5 N	5.2 N	....	- 3	- 6	-14
17	0 56 S	275 37	7.9 E	.....	...	0.1 E	0.0	0.1W	....	....	....
18	0 04 S	276 27	7.7 E	.....	...	0.3 E	0.1 E	0.2 E	....	....	....
18	0 17 N	277 06	.....	19.8 N	.326	3.8 N	5.5 N	....	- 3	- 6	-14

*Units of third decimal c. g. s.

TABLE 2.—Preliminary results of ocean magnetic observations on the *Carnegie* from Buenos Aires to Washington, D. C., December 1917 to June 1918—Continued.

Date.	Lat.	Long. east of Green- wich.	Carnegie values.			Chart differences.					
						Decl'n and Incl'n.			Hor. Int.		
			Decl'n.	Incl'n.	Hor. Int.	Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1918	° /	° /	°	°	<i>c.g.s.</i>	°	°	°	*	*	*
Apr. 18	0 23 N	277 20	7.2 E	.....	...	0.2 E	0.1 W	0.1 E	....	....	....
19	1 22 N	278 08	6.9 E	.....	...	0.2 E	0.1 W	0.2 E	....	....	....
19	1 48 N	278 35	.....	23.0 N	.323	3.9 N	5.2 N	.....	— 7	— 9	—17
19	1 55 N	278 44	6.7 E	.....	...	0.3 E	0.1 W	0.1 E	....	....	....
20	2 24 N	279 49	6.1 E	.....	...	0.1 E	0.5 W	0.0	....	....	....
20	2 32 N	280 03	.....	24.8 N	.324	3.8 N	5.2 N	.....	— 4	— 7	—14
20	2 40 N	280 09	5.9 E	.....	...	0.0	0.4 W	0.1 E	....	....	....
21	3 07 N	280 32	5.9 E	.....	...	0.2 E	0.3 W	0.2 E	....	....	....
21	3 36 N	280 45	.....	27.1 N	.324	4.3 N	4.9 N	.....	— 5	— 7	—14
21	3 47 N	280 49	5.7 E	.....	...	0.1 E	0.3 W	0.3 E	....	....	....
22	4 29 N	281 18	5.3 E	.....	...	0.0	0.5 W	0.1 E	....	....	....
22	5 19 N	281 31	.....	30.3 N	.322	4.4 N	4.6 N	.....	— 7	— 8	—15
23	6 40 N	281 41	4.4 E	.....	...	0.4 W	0.8 W	0.2 W	....	....	....
23	7 20 N	281 36	.....	33.7 N	.322	4.3 N	4.5 N	.....	— 8	— 8	—16
24	7 57 N	280 38	4.9 E	.....	...	0.1 E	0.1 W	0.3 E	....	....	....
May 12	10 30 N	280 29	.....	38.4 N	.320	3.6 N ¹	3.1 N ¹	.....	— 9 ¹	—11 ¹	—20 ¹
12	10 41 N	280 33	4.5 E	.....	...	0.2 E	0.2 E	0.3 E	....	....	....
13	11 07 N	280 33	4.5 E	.....	...	0.3 E	0.3 E	0.3 E	....	....	....
13	11 58 N	280 24	.....	40.4 N	.318	3.2 N	2.9 N	.....	— 9	—12	—20
13	12 11 N	280 25	4.3 E	.....	...	0.3 E	0.3 E	0.3 E	....	....	....
14	13 03 N	280 19	4.2 E	.....	...	0.4 E	0.4 E	0.4 E	....	....	....
14	13 41 N	280 11	.....	42.9 N	.314	2.7 N	2.7 N	.....	—11	—15	—22
14	13 54 N	280 07	4.0 E	.....	...	0.3 E	0.3 E	0.4 E	....	....	....
15	13 49 N	280 11	4.0 E	.....	...	0.3 E	0.3 E	0.4 E	....	....	....
15	14 09 N	279 23	.....	43.4 N	.314	2.3 N	2.7 N	.....	—11	—15	—23
15	14 19 N	279 10	4.2 E	.....	...	0.3 E	0.4 E	0.3 E	....	....	....
16	15 30 N	278 45	4.6 E	.....	...	0.8 E	0.8 E	0.8 E	....	....	....
16	16 12 N	278 24	.....	46.0 N	.310	1.9 N	2.9 N	.....	—12	—17	—24
16	16 27 N	278 16	4.2 E	.....	...	0.4 E	0.4 E	0.6 E	....	....	....
17	17 34 N	277 41	4.3 E	.....	...	0.5 E	0.5 E	0.7 E	....	....	....
17	18 14 N	277 10	.....	48.6 N	.306	1.9 N	2.9 N	.....	—13	—18	—25
17	18 31 N	277 00	4.2 E	.....	...	0.3 E	0.4 E	0.6 E	....	....	....
18	19 35 N	276 33	4.6 E	.....	...	0.8 E	0.8 E	1.0 E	....	....	....
18	20 26 N	276 05	.....	51.1 N	.300	2.0 N	3.0 N	.....	—15	—21	—25
18	20 40 N	275 53	4.6 E	.....	...	0.7 E	0.8 E	0.8 E	....	....	....
19	21 06 N	275 02	4.9 E	.....	...	0.7 E	1.0 E	0.8 E	....	....	....
19	21 30 N	274 34	.....	52.1 N	.300	1.9 N	3.2 N	.....	—13	—18	—22
19	21 40 N	274 24	4.7 E	.....	...	0.3 E	0.6 E	0.4 E	....	....	....
20	22 59 N	273 48	5.2 E	.....	...	0.7 E	1.0 E	0.6 E	....	....	....
20	23 48 N	273 43	.....	54.8 N	.290	1.6 N	2.8 N	.....	—17	—18	—22
20	23 49 N	273 50	4.6 E	.....	...	0.2 E	0.4 E	0.0	....	....	....

¹Charts used after April 24, 1918: U. S. Hydrographic Office Chart No. 2406 for 1915 and No. 1701 for 1900; British Admiralty Charts No. 3777 for 1917, Nos. 3598 and 3603 for 1907; Reichs-Marine-Amt Charts Tit. XIV, No. 2 for 1910, Tit. XIV, Nos. 2a and 2b for 1905. The chart differences are obtained by subtracting corrected chart values, derived as explained in previous sentence, from the observed *Carnegie* values. The letter *E* signifies that the chart value for east declination is smaller, or the chart value for west declination larger, than the *Carnegie* value; *W* signifies the reverse. The letter *N* signifies that the derived chart value for northerly inclination is smaller, or for southerly inclination larger, than the *Carnegie* value; *S* signifies the reverse. The plus sign signifies that the derived chart value for horizontal intensity is smaller than the *Carnegie* value, the minus sign meaning, of course, the reverse.

*Units of third decimal c. g. s.

TABLE 2.—Preliminary results of ocean magnetic observations on the *Carnegie* from Buenos Aires to Washington, D. C., December 1917 to June 1918—Continued.

Date.	Lat.	Long. east of Green- wich.	Carnegie values.			Chart differences.					
						Decl'n and Incl'n.			Hor. Int.		
			Decl'n.	Incl'n.	Hor. Int.	Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1918	° ' "	° ' "	°	°	c.g.s.	°	°	°	*	*	*
May 21	23 15 N	274 28	5.0 E	.....	...	0.8 E	1.1 E	0.6 E	....	....	....
21	24 04 N	274 44	.....	55.2 N	.286	1.3 N	2.2 N	.....	-18	-18	-24
21	24 19 N	274 49	4.7 E	.....	...	0.7 E	0.9 E	0.5 E	....	....	....
22	23 44 N	275 44	4.4 E	.....	...	0.8 E	0.9 E	0.6 E	....	....	....
22	23 33 N	276 12	.....	55.2 N	.288	2.0 N	2.4 N	.....	-17	-17	-24
22	23 50 N	276 11	4.1 E	.....	...	0.7 E	0.7 E	0.5 E	....	....	....
23	23 37 N	277 02	3.9 E	.....	...	0.8 E	0.8 E	0.6 E	....	....	....
23	23 53 N	277 10	.....	55.7 N	.283	1.7 N	2.6 N	.....	-19	-20	-26
23	23 37 N	277 27	3.1 E	.....	...	0.3 E	0.3 E	0.0	....	....	....
24	23 40 N	278 21	.....	55.5 N	.283	1.5 N	2.3 N	.....	-19	-19	-27
24	23 48 N	278 28	3.0 E	.....	...	0.6 E	0.8 E	0.5 E	....	....	....
25	24 27 N	279 17	.....	56.8 N	.278	1.6 N	2.7 N	.....	-19	-20	-27
25	24 44 N	279 25	2.5 E	.....	...	0.7 E	0.9 E	0.8 E	....	....	....
26	25 04 N	280 00	2.2 E	.....	...	0.8 E	0.9 E	0.9 E	....	....	....
26	25 35 N	280 11	.....	58.2 N	.272	1.8 N	2.3 N	.....	-18	-20	-27
26	26 10 N	280 13	1.5 E	.....	...	0.4 E	0.4 E	0.7 E	....	....	....
27	28 11 N	280 17	0.7 E	.....	...	0.5 E	0.0	0.7 E	....	....	....
27	29 01 N	280 08	.....	61.9 N	.255	1.9 N	1.6 N	.....	-19	-21	-23
27	29 25 N	280 10	0.4 E	.....	...	0.4 E	0.2 E	0.6 E	....	....	....
28	30 26 N	280 49	0.1 W	.....	...	0.5 E	0.4 E	0.7 E	....	....	....
28	30 44 N	281 04	.....	63.6 N	.244	2.0 N	1.3 N	.....	-21	-23	-22
28	30 50 N	281 10	1.0 W	.....	...	0.0	0.1 W	0.3 E	....	....	....
29	31 09 N	281 41	1.4 W	.....	...	0.0	0.1 W	0.3 E	....	....	....
29	31 14 N	281 52	.....	63.8 N	.242	1.3 N	1.0 N	.....	-18	-22	-18
29	31 18 N	281 55	1.4 W	.....	...	0.2 E	0.1 W	0.5 E	....	....	....
30	31 42 N	282 05	1.3 W	.....	...	0.5 E	0.4 E	0.8 E	....	....	....
30	31 54 N	282 22	.....	64.8 N	.235	1.8 N	1.5 N	.....	-19	-23	-21
30	32 00 N	282 32	2.0 W	.....	...	0.3 E	0.3 E	0.8 E	....	....	....
31	32 28 N	283 24	2.8 W	.....	...	0.2 E	0.0	0.8 E	....	....	....
31	32 52 N	284 15	.....	65.5 N	.230	1.4 N	0.8 N	.....	-17	-18	-15
31	33 01 N	284 33	4.4 W	.....	...	0.4 W	0.8 W	0.0	....	....	....
June 1	33 43 N	285 16	4.9 W	.....	...	0.1 W	0.5 W	0.1 E	....	....	....
1	33 54 N	285 39	.....	66.7 N	.221	1.5 N	1.0 N	.....	-18	-20	-16
1	33 54 N	285 43	5.4 W	.....	...	0.2 W	0.7 W	0.2 W	....	....	....
2	34 08 N	286 07	5.6 W	.....	...	0.0	0.3 W	0.3 E	....	....	....
2	34 46 N	285 51	.....	67.4 N	.216	1.3 N	0.8 N	.....	-17	-16	-16
2	35 10 N	285 45	6.3 W	.....	...	0.4 W	0.7 W	0.2 W	....	....	....
3	36 02 N	285 29	6.9 W	.....	...	0.7 W	1.0 W	0.7 W	....	....	....
3	36 07 N	285 04	.....	68.4 N	.209	1.0 N	0.7 N	.....	-13	-14	-16
3	36 09 N	284 49	5.7 W	.....	...	0.1 E	0.1 W	0.0	....	....	....
4	36 11 N	284 34	5.8 W	.....	...	0.2 W	0.4 W	0.4 W	....	....	....
8	37 19 N	283 51	6.2 W	.....	...	0.4 W	0.5 W	0.6 W	....	....	....
9	38 12 N	283 44	6.2 W	.....	...	0.1 W	0.2 W	0.2 W	....	....	....
9	38 13 N	283 44	.....	70.1 N	.196	0.6 N	0.4 N	.....	-12	-12	-12
10	38 14 N	283 07	6.0 W	.....	...	0.4 W	0.3 W	0.5 W	....	....	....

*Units of third decimal c. g. s.

After completing all arrangements for closing up the work of the vessel during Cruise V, the *Carnegie* was placed out of commission at Washington, June 30, 1918.

During the nine years since the *Carnegie* was placed in commission she has cruised over 189,176 nautical miles of ocean, the daily average for the 1,587 days at sea being 119 miles. Magnetic declination observations were made at 2,155 stations at sea, magnetic intensity observations at 1,387 stations, and inclination observations at 1,393 stations.

LAND WORK.

AFRICA.

On November 29, 1917, Observer H. E. Sawyer arrived at Khartoum, Anglo-Egyptian Sudan, having left El Fasher, in the Darfur, on October 3, and El Obeid on November 17, thus completing a very difficult overland journey, beginning at Brazzaville, near the mouth of the Kongo River, and extending by way of Lake Tchad to the Upper Nile Valley, and covering almost exactly a year's time. It is pleasing to note that the trip was accomplished with no serious mishap and that the loss of time on account of sickness was relatively small, considering the prevalence of tropical disease, the unavoidable exposure, and the lack of suitable facilities for proper treatment.

After a period of rest and recuperation at Khartoum, Mr. Sawyer outfitted a felucca, a combination sail and row boat, for an expedition southward up the White Nile, having been informed that the prevailing north wind and moderate stage of the water at that season would permit easy traveling by night with opportunity to land and make observations at frequent intervals by day. However, a very unusual condition of high water in the lakes at the head of the Nile maintained the river at such a stage that suitable landings could not be made as often as had been hoped. He left Khartoum on January 12, 1918, and arrived at Kodok (Fashoda) on February 4, whence he proceeded to Gondokoro, Uganda, where Dr. J. C. Beattie concluded his overland expedition from South Africa in 1909. Notwithstanding the difficulties incident to the high water, 16 stations were occupied along the Nile above Khartoum.

On his return to Khartoum, Mr. Sawyer received an invitation from a representative of the government of Eritrea, who chanced to be at Khartoum at that time on business, to accompany him on his return to Asmara, Eritrea, by automobile. This trip, which occupied 17 days from April 25, furnished opportunity to occupy 4 intermediate stations between Khartoum and Asmara, one of which was Kassala, a station of the Magnetic Survey of Egypt. After observing at Asmara, previously occupied by Mr. W. F. Wallis, of the Department, in 1914, he proceeded to Massawa and Port Sudan on the Red Sea, where C. I. W. repeat stations of 1911 and 1914 were reoccupied. From Port Sudan he returned by way of Musmar and Berber to the Nile, and thence down the Nile to Helwan, near Cairo, occupying en route

about 15 selected stations of the Magnetic Survey of Egypt. After comparing his magnetic instruments with those of the observatory at Helwan, Mr. Sawyer began his homeward voyage, by way of the Pacific, occupying repeat stations of the Department as opportunity offered.

ASIA.

In the progress of the expedition through the provinces of south-eastern China, which started from Canton in August 1917, Observer Frederick Brown arrived at Hangchow, Chekiang, on October 27, and reoccupied the C. I. W. station of 1906. From Hangchow the journey was made to Shanghai by rail, and thence to Lukiapang, the location of the magnetic branch of the Zikawei Observatory, where a complete series of intercomparisons was made between the instruments used by Mr. Brown and those of the Observatory. After these intercomparisons, he observed at the C. I. W. station at Ningpo and proceeded by steamer to Wenchow, Chekiang, which was occupied on November 10. There being no direct steamer line from Wenchow southward, Mr. Brown decided to make the inland trip partly by canal and partly overland on foot, being able by this method to observe at 5 intermediate points between Wenchow and Foochow, Fukien, where he arrived on November 24 and reoccupied the C. I. W. station of 1906.

Continuing southward, observations were made by Mr. Brown at the repeat stations at Amoy and Swatow and at two other intermediate points en route to Hongkong, which was reached on December 9, 1917. About 3,000 miles was covered on this trip and 37 stations were occupied, 7 of which had been previously occupied by observers of the Department. At the conclusion of this work, Mr. Brown secured a comparison at Canton between the instruments used by him and an outfit belonging to the Department held in reserve at Canton. In this work he was assisted by Dr. C. K. Edmunds, whose duties as president of Canton Christian College had not permitted him to take any extended part in the survey work of the year. Mr. Brown then proceeded to Washington, where he arrived about the first of February 1918.

NORTH AMERICA.

Observations were made on June 8, 1918, the day of the total eclipse of the sun, by parties in the United States, as follows: By the Director, assisted by E. W. Elder and R. Sutton at Corona, at an altitude of about 11,800 feet, in the Colorado Rocky Mountains; by a party in charge of S. J. Mauchly, assisted by D. M. Wise, A. Thomson, and M. B. Smith, at Lakin, Kansas; by H. W. Fisk, assisted by C. C. Ennis, at Goldendale, Washington; by C. W. Hewlett at Brewton, Alabama, in the belt of totality; by W. J. Peters at Lake Moraine, near Pikes Peak, Colorado; and by C. R. Duvall, at Washington, outside the path of totality. In addition, observations were made by G.

L. Hosmer, at Woburn, near Boston, Massachusetts, by C. T. Knipp at Urbana, Illinois, by H. B. Wahlin at Columbia, Missouri, by J. M. Kuehne, at Austin, Texas, and by W. J. Raymond at Berkeley, California; these observers acted under the direction of the Department and cooperated with it. At Lakin a set of magnetograph instruments was put into operation, in charge of Observer D. M. Wise, assisted by A. Thomson and M. B. Smith. Some special observations were also made in the neighborhood of Pikes Peak for the purpose of studying the possible effect of altitude on the values and variations in the magnetic elements due to change of altitude.

SOUTH AMERICA.

After crossing the Andes from the Pacific coast by way of La Paz and the Beni River, Observer Allen Sterling arrived at Manaos, Brazil, on October 29, 1917. The plan had been to ascend as many of the tributaries of the Amazon as suitable opportunity should afford, but difficulties arising (chiefly from economic conditions) limited the number of these to two, the Purus and the Tapajoz. After considering the different plans for ascending the Purus River, Mr. Sterling decided to rely on the unscheduled but rather frequent river steamers for transportation from point to point. In this way he succeeded in establishing 8 stations between Manaos and Xapury on the Acre River, an affluent of the upper Purus, having left Manaos on November 20 and arriving at Xapury on January 8, 1918. Returning over the same route to Manaos, he proceeded eastward to Santarem, and from there to Obidos, where he observed at the C. I. W. station of 1911, on February 10.

Returning to Santarem, also a repeat station, Mr. Sterling arranged a short trip up the Tapajoz River, which he succeeded in ascending as far as its confluence with the São Manoel River. The first portion of this journey was made by river steamer, after which it was necessary to make use of cargo boats propelled by motor in part, and handled in difficult places by a crew of oarsmen, assisted by the passengers as required. He succeeded in making observations at three points, a greater number being made impracticable by the serious illness of a member of the crew which prevented making the necessary stops. As no further side expeditions seemed to be feasible, Mr. Sterling went directly to Para after his return to Santarem, making one stop at Almeirim, a C. I. W. station of 1911. From Para 4 stations were occupied in the immediate vicinity, including the repeat station of Pinheiro.

Leaving Para on May 13, Mr. Sterling observed at Cayenne, Paramaribo, Georgetown, and New Amsterdam, in the Guianas, finally leaving Georgetown for New York, where he arrived on July 8, 1918. Since arriving at Manaos in October, Mr. Sterling occupied 26 stations, 8 of which were exact or close reoccupations of stations pre-

viously occupied by observers of the Department, and all of which were in the jungle regions of the Amazon or the Guianas. As must be expected in such cases, some time was lost on account of sickness from malaria and other tropical disorders, but, largely on account of the close observance of precautions recommended for traveling in such regions, the sickness was never severe and the loss of time was comparatively small.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

Sea surface-temperature and meteorological observations made on the *Carnegie* during her sub-Antarctic cruise, December 6, 1915, to April 1, 1916. J. P. Ault. Terr. Mag., vol. 22, 183-189 (December 1917), Washington.

This paper contains the results of sea surface-temperature and meteorological observations made on board the *Carnegie* during her sub-Antarctic cruise, December 6, 1915-April 1, 1916, from Lyttelton (New Zealand) to South Georgia and Lyttelton. Reports that have thus far come from this region are few and incomplete, and as the part of the Great Southern Ocean traversed is the scene of such rapid and extreme changes in meteorological conditions, any additional information on the subject is of interest. The *Carnegie* made a complete circumnavigation of the globe from west to east, mainly between the parallels of latitude 50° and 60° south, in one season, the summer of 1915-16, during which Sir Ernest Shackelton's expedition was meeting with such serious reverses. The meteorological observations made by the two parties of his expedition, and those obtained on the *Carnegie*, are especially valuable because they are contemporaneous records of the conditions prevailing in different parts of the southern regions at that time.

Relation between the secular variation of the earth's magnetism and solar activity. L. A. Bauer. Terr. Mag., vol. 23, 1-22, 61-68 (March and June 1918), Washington.

In a previous paper entitled "Solar radiation and terrestrial magnetism," the possibility was pointed out that irregularities in the annual changes of the Earth's magnetic elements, the so-called secular variation, might be associated with such manifestations of solar activity as are revealed to us by changes in the solar constant of radiation.* As the result of a preliminary investigation, the following conclusion was reached in that paper:

If the quiet-day magnetic effect were to persist throughout the year, it would cause a secular variation fully 10 times that generally observed. However, the quiet days are in the minority, being exceeded 3 times and more by unquiet days, on which the magnetic effect is of an opposite kind to that of the quiet day. Since these acyclic effects appear to be associated with solar changes and since the latter are not periodic, but more or less sporadic, there is an outstanding effect at the end of the year which causes an irregularity in the regularly progressing secular change. Accordingly, there should be found some correspondence between annual changes of the solar constant and annual magnetic changes. This is found to be the case. Since the solar-constant changes occur only approximately in accordance with sun-spot activity, and since the magnetic changes are found to conform closely to those in the solar constant, an explanation is found as to why the irregularities in the magnetic secular change do not always synchronize with changes in solar activity as measured by the sun-spot numbers, nor correspond in magnitude to them.

*Terr. Mag., vol. 20, 1915, pp. 155 and 157.

The formulæ for the function G , used chiefly in this investigation, were developed in the author's article on "The Local Magnetic Constant and Its Variations."*

The chief purpose of the present investigation is to find out, if possible, how the intensity of magnetization of the Earth may vary and how these changes may be related to changes in solar activity.

It is stated in conclusion that when the present sun-spot maximum has been well passed and thus a few more years of observations of both magnetic and solar quantities are available, it will be more easily possible to determine the magnetic effects to be associated respectively with sun-spot activity and solar-constant changes.

It would seem that we have ample evidence that the Earth's absolute magnetic state at any time is dependent upon solar conditions, and that an appreciable portion of the secular variation of the Earth's magnetism may be associated with changes in solar activity. In general, the effect of increased solar activity is to cause a decrease in the Earth's intensity of magnetization, though there may also at times be reverse effects.

Results of magnetic and allied observations made during the solar eclipse of June 8, 1918. L. A. Bauer, H. W. Fisk and S. J. Mauchly. *Terr. Mag.*, vol. 23, 95-110, 151 (Sept. and Dec. 1918), Washington.

The solar eclipse of June 8, 1918, offered an exceptional opportunity for magnetic and allied observations, since somewhat over one-third of the belt of totality was situated in the United States. An interesting circumstance was also the fact that this eclipse was the repetition of the one of May 28, 1900, in connection with which systematic observations according to the first author's directions, for the study of a possible magnetic effect during a total solar eclipse, were made. The belt of totality of the latter eclipse passed through the southeastern part of the United States during the morning hours, whereas that for the eclipse of June 8, 1918, passed through the United States from northwest to southeast during the *afternoon* hours. Thus conditions were, in a certain sense, reversed for the two eclipses, as far as the regular diurnal variation of the earth's magnetism is concerned.

In response to the appeal sent out by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, cooperation was received from various magnetic observatories, institutions, and universities situated within the entire zone of visibility, as well as from certain places outside of this zone. As the result of this appeal magnetic data are available at present from 7 stations within the belt of totality, 16 stations outside of the belt but within the zone of visibility of the eclipse, and 3 stations outside of the zone; the stations covered the region of the Earth from China, Australia, and the Philippines to Porto Rico. Of this list the Coast and Geodetic Survey contributed data at 8 stations, and the Department of Terrestrial Magnetism at 7 stations, besides the data at 5 university stations working in cooperation with the Department. Canadian governmental institutions contributed data at 3 stations in Canada; the data at the remaining stations were received from the observatories at Kakioka, Japan, Lukiapang, China, and Antipolo, Philippine Islands.

At Lakin, Kansas, where was located the Smithsonian Institution party, a temporary magnetic observatory was established by the Department, and a full program of magnetic and atmospheric-electric observations was carried out; this station was in charge of S. J. Mauchly. At Mr. Fisk's station, Goldendale, Washington, where the Lick Observatory party was located,

**Terr. Mag.*, vol. 19, 1914, p. 114.

complete observations for determining the changes in magnetic declination and horizontal intensity were made. With a view of varying the conditions, the station selected by L. A. Bauer for his work was at Corona, Colorado, the elevation of which was 11,800 feet; the changes in magnetic declination observed during the eclipse at this mountain station proved to be of special interest.

The various curves based on the results of the magnetic observations at the different stations, especially in the zone of visibility, show a number of interesting features. For several days prior to the day of the eclipse, sun-spot activity was very pronounced; while on June 8 there were still some spots visible, they were near the sun's western edge and at stations in moderate latitudes apparently did not cause magnetic disturbances, such as occur during the time of a cosmic magnetic storm. The conditions for observing the minute magnetic effects to be associated with the solar eclipse were therefore favorable, and the various curves clearly indicate that such effects were observed. It is pointed out that, in general, the most notable effects revealed by the magnetic curves did not occur according to absolute time nor according to local mean time, but followed closely the times at which the eclipse occurred at the different stations. The stations in the United States also revealed magnetic effects before the time of the local eclipse resulting evidently from the easterly progression of the effects which had arisen in the portion of the earth over which the eclipse had already occurred.

Not only were the conclusions reached with reference to the eclipse of May 28, 1900, and subsequent eclipses, verified by the effects observed during the eclipse of June 8, 1918, but a number of additional facts have been disclosed which will assist materially in the final analysis of this interesting phenomenon. It was again shown that the magnetic fluctuations observed during the eclipse are analogous in their nature to the solar diurnal variation, differing from it only in degree. Retardations and interruptions in the usual curves of the diurnal variation, as found during the previous eclipses since 1900, were again distinctly evident in the magnetic curves applying to the eclipse under discussion.

The average range in the fluctuations of the horizontal intensity was about 0.03 per cent, in the vertical intensity about 0.02 per cent. The average range of the fluctuations in the magnetic declination varied from 1 to 2 minutes of arc.

An approximate estimate of the magnitude of the effect as shown by the observed changes in horizontal intensity and vertical intensity is that the effect was about equivalent to that associated by the first author with a ten per cent change in the solar radiation, as indicated by the values of the solar constant observed under the auspices of the Smithsonian Institution.

Brief reference is made to the various causes which might be responsible for the observed magnetic effects during an eclipse and how it would be possible, upon the basis of the accumulated data, to make a test of the various hypotheses.

Preliminary results of ocean magnetic observations on the *Carnegie* from Buenos Aires to Talcahuano, Dec. 1917-Jan. 1918. H. M. W. Edmonds. Terr. Mag., vol. 23, 23-24 (Mar. 1918). Washington.

Preliminary results of ocean magnetic observations on the *Carnegie* from Talcahuano to Balboa, Jan.-April 1918. H. M. W. Edmonds. Terr. Mag., vol. 23, 69-72 (June 1918). Washington.

Preliminary results of ocean magnetic observations on the *Carnegie* from Balboa to Washington, D. C., April-June 1918. H. M. W. Edmonds. Terr. Mag., vol. 23, 139-140 (Sept. 1918). Washington.

These three papers by H. M. W. Edmonds, in command of the *Carnegie*, give the results of the magnetic observations on the *Carnegie* and the chart corrections as found for the period December 1917 to June 1918. The results will be found in the present annual report. (See pages 249-255.)

Instructions issued by France and United States concerning protection of Cook's third expedition, returning to England. H. M. W. Edmonds. *Terr. Mag.*, vol. 23, 143 (Sept. 1918), Washington.

The following extracts from Arthur Kitson's book "Captain James Cook, R. N., F. R. S. The Circumnavigator," pages 355-356, will be of interest at the present time.

"It may conveniently be noted here that, on the arrival of the *Resolution* and *Discovery* at Macao, on their way home in 1780, they were informed that England was at war with France and the American colonies; so to preserve a record for the Admiralty in case of capture, Burney made a copy of the whole of his log on thin Chinese paper. * * * This precaution was in reality unnecessary, for on the declaration of war the French Minister, M. de Sartines, wrote the following instructions to the Navy:

"'Captain Cook, who sailed from Plymouth in July, 1776, on board the *Resolution*, in company with the *Discovery*, Capt. Clerke, in order to make some discoveries on the coasts, islands and seas of Japan and California, being on the point of returning to Europe, and as such discoveries are of general utility to all nations, it is the King's pleasure that Capt. Cook shall be treated as a commander of a neutral and allied power, and that all Captains of armed vessels, etc., who may meet that famous navigator, shall make him acquainted with the King's order on this behalf, but at the same time let him know that on his part he must refrain from all hostilities.'

"Fiske in his 'American Revolution' also says:

"'When Franklin was in Paris as representative of the United States he was empowered to issue Letters of Marque against the English, but in doing so, inserted an instruction that if any of the holders should fall in with vessels commanded by Captain Cook, he was to be shown every respect and be permitted to pass unattacked on account of the benefits he had conferred on mankind through his important discoveries.'"

The Royal Society of London later made recognition of the courtesies thus shown to Cook's Expedition. Quoting from the book on "The Life of Captain James Cook," by A. Kippis, London, 1788, page 512:

"Of the gold medals which were struck on this occasion, one was presented to His Majesty, another to the Queen and a third to the Prince of Wales. Two were sent abroad, the first to the French King, on account of the protection he had granted to the ships under the command of Captain Cook; and a second to the Empress of Russia, in whose dominions the same ships had been received and treated with every degree of friendship and kindness." After the general assignment of these medals in 1784, one was also bestowed upon Franklin.

According to the Marquis of Condorcet, the French measure "originated in the liberal and enlightened mind of that excellent citizen and statesman, Monsieur Turgot." The original text of the passage* from Condorcet's *Life of Turgot*, is as follows:

"Dans le moment où la guerre se déclara, M. Turgot vit combien il seroit honorable à la Nation Française que le vaisseau de Cook fût respecté sur les mers. Il dressa un Mémoire pour exposer les motifs d'honneur, de raison, d'intérêt même qui devoient dicter cet acte de respect pour l'humanité; &

*From "Vie de M. Turgot" by J. A. M. C. Condorcet, London, 1787, p. 203.

c'est sur son Mémoire, dont pendant toute sa vie l'auteur est resté inconnu qu'a été donné l'ordre de ne pas traiter en ennemi le bienfaiteur commun de toutes les nations européennes."

Kippis, on pages 477-478 of the work cited, makes the statement that the American Congress did not support Franklin's action; however, no evidence has been found for this assertion. The instructions issued by Franklin, 9 days prior to those of M. de Sartines, are as follows:

PASSPORT FOR CAPTAIN COOK.*

To all Captains and Commanders of armed Ships acting by Commission from the Congress of the United States of America, now in War with Great Britain.

Gentlemen,

A Ship having been fitted out from England before the commencement of this War, to make Discoveries, of new Countries, in Unknown Seas, under the Conduct of that most celebrated Navigator and Discoverer, Captain Cook; an Undertaking truly laudable in itself, as the Increase of Geographical Knowledge facilitates the Communication between distant Nations, in the Exchange of useful Products and Manufactures, and the Extension of Arts, whereby the common Enjoyments of human Life are multiply'd and augmented, and Science of other kinds encreas'd to the Benefit of Mankind in general; This is therefore most earnestly to recommend to every one of you, that in case the said Ship, which is now expected to be soon in the European Seas on her Return, should happen to fall into your Hands, you would not consider her as an Enemy, nor suffer any Plunder to be made of the Effects contain'd in her, nor obstruct her immediate Return to England, by detaining her or sending her into any other Part of Europe or to America, but that you would treat the said Captain Cook and his People with all Civility and Kindness, affording them, as common Friends to Mankind, all the Assistance in your Power, which they may happen to stand in need of. In so doing you will not only gratify the Generosity of your own Dispositions, but there is no doubt of your obtaining the Approbation of the Congress, and your other American Owners. I have the honour to be, Gentlemen, your most obedient humble Servant.

Given at Passy, near Paris, this 10th day of March, 1779.

B. FRANKLIN,

Plenipotentiary from the Congress of the United States to the Court of France.

Latest annual values of the magnetic elements at observatories. J. A. Fleming. Terr. Mag., vol. 22, 169-172 (December 1917).

A compilation of the most recent annual values of the magnetic elements at observatories distributed over the Earth.

A study of pressure and temperature effects in earth-current measurements. S. J. Mauchly. Terr. Mag., vol. 23, 73-91 (June 1918), Washington. (Abstracts) Jour. Wash. Acad. Sci., vol. 8, No. 11, 371 (June 4, 1918), Washington; Sci. Abstr., A, vol. 21, No. 249, 391-392 (Sept. 30, 1918), London. (Paper presented before the Philosophical Society of Washington, April 13, 1918.)

A large part of the earth-current data at present available were obtained from observations made on commercial telegraph lines. For a line of considerable length the fluctuations in the observed current are generally assumed to be very little influenced by local effects at the earth plates, but for measurements made between electrodes not many kilometers apart this assumption

*From MS. copy in the Library of Congress, Washington, D. C.

is not valid. Since most of the special lines installed for the study of earth-current phenomena are necessarily limited in extent, the object of the experiments described was to investigate the nature and order of magnitude of some of the spurious effects which may function under these conditions.

In one group of experiments a method similar to that used by Des Coudres, in his study of the E. M. F. produced by the action of gravity in salt solutions, was used to investigate the possible presence of an effect due to difference of pressure at the electrodes. It was found that a tube filled with soil and provided with an electrode at either end showed a component of the total E. M. F. which when the tube was vertical tended to form a cathode at the lower electrode regardless of which electrode was involved. The order of magnitude of this effect was found to be sufficient to account for certain observed phenomena which appear inconsistent with physical principles, provided the effect exists as a general phenomenon in nature. For example, it would account for what has been called a vertical earth-current of density much larger than that of either the horizontal earth-current or the vertical air-earth current. It would also account for the fact that many observers have found the "vertical earth-current" to be nearly free from diurnal variation.

Inasmuch as our knowledge of the interrelations between earth-currents and terrestrial magnetism must come from a study of the variations involved, it is important to know to what extent observed earth-current variations are genuine. One phase of this question was investigated at Washington (as indicated on page 254 of annual report of the Director of the Department of Terrestrial Magnetism for 1917) by means of two pairs of similar electrodes, each pair being in the same vertical, one pair being inclosed in an insulating tube and the other being free, the corresponding electrodes of the two circuits, however, being at the same level. Continuous measurements of P. D. and temperature difference were made on these circuits extending over a period of about 8 months in 1916 and 1917. The results show that most if not all of the diurnal variation which some observers have ascribed to a vertical earth-current is very probably due to variations in temperature difference between the electrodes.

The spurious effects introduced by temperature-difference variations were found to be greatly increased and reversed in sign when the soil in contact with the upper electrodes was frozen.

While the results are strictly applicable only to the actual installation employed during the experiments, they show that the effects which may result from temperature difference at the electrodes of an earth-current line, and from variations in this difference, may, for short lines, be of the same order of magnitude as the quantities to be measured and with which they are associated. In the light of these experiments it appears that some of the phenomena which various observers have ascribed to a true earth-current must be largely caused by such temperature-difference effects. Although proper emphasis is usually placed on the employment of non-polarizable electrodes for earth-current measurements, it appears not always to have been appreciated that with the electrodes customarily used this does not prevent the introduction of temperature-difference effects.

Results of dip-of-horizon measurements made on the *Galilee* and *Carnegie*, 1907-1917. W. J. Peters. Terr. Mag., vol. 23, 47-60 (June 1918). Washington.

Since all astronomic positions at sea depend upon sun-altitudes or star-altitudes measured from the horizon, it is evident that the precision of the determinations of the geographic positions for the magnetic stations at sea

will be affected by the error of that value of the refraction which is used in calculating the dip of the horizon. Although the atmospheric refraction is usually small, reports of extraordinary values from time to time have shown the desirability of extensive investigation, and a number of observations have been made, principally by German investigators during the last 30 years. Koss, who prepared the first tables of dip-of-horizon that have a temperature argument, has observed the horizon 10' above its normal position and 3' below. A German epitome* states that the horizon has been observed 15' above and 3' below its normal position. Bowditch† says that reliable observations have frequently placed it 10' above, and values as high as 32' have been recorded. The significance of these figures will be realized when it is remembered that each minute of abnormal refraction means an error of one mile in the position of the ship.

Such extraordinary values of the refraction at the horizon, as cited in the previous paragraph, have not been found during 10 years of work at seas by the Department of Terrestrial Magnetism, covering all the oceans. Whether large abnormal values occur along the borders of equatorial and polar currents shallows, and waters swept by very warm or very cold breezes blowing off land, regions in which the cruises of the Galilee and Carnegie have not been prolonged, requires further investigation. In all the observations taken first on the Galilee, then continued on the Carnegie, amounting to 3,031 determinations, the refraction has not raised the horizon more than 2'.4, nor depressed it more than 2'.0 below the position in which it would be seen if no refraction existed. The observations were made mostly at heights above sea of 24 and 18 feet. The maximum raising of the horizon, +2'.4, was found on two consecutive days, October 29 and 30, 1915, between New Zealand and Australia; there was a heavy sea at the time and the horizon was noted as "rough." The next maximum raising, +2'.2, was also observed on two consecutive days, February 9 and 10, 1908, in latitude 41° S., longitude 111° W., when a very high sea, with clear, well-defined horizon, was noted. Values of +2'.0 occur quite frequently, that is, about 1' above the average refraction at sea. The maximum depression, +2'.0 occurs only once in the 10 years, and was observed August 11, 1914, in latitude 71° N., longitude 5° W., with well-defined horizon and good conditions generally; the position is on the northern edge of the Gulf Stream, and not far from the ice floes of Greenland Sea, in a region where atmospheric conditions are subject to marked changes. Negative values are more rare than positive.

All methods in use, up to the present time, for measuring the refraction at the horizon, depend on one common principle—that of measuring the vertical angle between two diametrically opposite points of the horizon or of measuring the difference between this angle and 180°. This principle, common to all methods, is objectionable because it must be assumed in general that the refraction is the same for opposite points of the horizon. It is possible that unusual values might be observed on occasions when the direction of the abnormal value might be assigned with some degree of plausibility—for example, when it is observed from near the edge of an ocean current that may be plainly traced from the vessel, or when mirages occur limited to a small part of the horizon, or by the adjustment of many observations taken about the same time well distributed around the horizon. Experience, however, on the *Galilee* and *Carnegie*, shows that the first two suggestions could be used only on very rare occasions, and the last is not practical on a

*Lehrbuch der Navigation, herausgegeben vom Reichs-Marine-Amt, second edition, Berlin 1906, p. 110.

†Bowditch, N.: American Practical Navigator, Washington, 1914, p. 117.

sailing vessel, where the sails will always interfere with an uninterrupted view of the horizon at height of 18 feet above water. Heights much less than 18 feet are not desirable in investigations of the refraction.

Among the *instruments available for measuring the dip-of-horizon at sea* are prismatic and reflecting circles, sextants, Troughton's dip sector, the Blish attachment, and Kohlschütter's device for sextants, and the dip-of-horizon measurer by Pulfrich. The prismatic circle, sextant, and dip-of-horizon measurer have been tried on the *Galilee* first, subsequently on the *Carnegie*, but none of these instruments has been found entirely satisfactory. The prismatic circle was acquired primarily for land observations and was found to be so unwieldy at sea that only a few experiments were attempted. The principal objections to using sextants are the restriction imposed by the limits of their arcs, the amount of computing usually required to obtain the dip, and the periodic errors of the instrument, which are difficult to control; these errors, of little importance in navigation, are likely to be quite serious in attempts to measure fluctuations in refraction no larger than a fraction of a minute. The most promising instrument at first seemed to be *Pulfrich's dip-of-horizon measurer*,* made by Zeiss, of Jena. It consists of a low-power telescope, at the object-end of which is attached a box containing a system of three reflecting prisms. Rays from opposite points of the horizon enter through perforations or windows, one on either side of the box. They are reflected by the three prisms into the telescope. The images of the two opposite portions of the horizon appear rotated 90° to a vertical position with a light band, the sky, between them. The dip-of-horizon is one-half the angular width of this band, provided, of course, that the instrument is in perfect adjustment. The difficulties of observing with this instrument at sea are increased by the motions of the images as the observer tries to hold the instrument steady. The chief objection is a scissors-like motion which apparently no amount of practice will eliminate; it is caused by changes in the inclination of the telescope to the horizontal.

Besides the obstacles to precision which are inherent in this instrument, there are others which affect all instruments. The actual conditions of visibility, etc., of course, are taken care of by the observer's remarks, and these observations may be weighted or rejected, as desired. *One constant source of error is in the height of instrument adopted.* Did no refraction exist, the dip-of-the-horizon could be computed for a given height of instrument with more precision than it could be measured. The difference between this computed dip and the dip observed being regarded as the refraction for the given height, it will be in error by the same amount as the computed dip, if the latter is in error. Suppose the given height of about 18 feet to be in error by 1 foot, the refraction deduced will have an error of 0'.12.

The *height of instrument* is measured in smooth water, as it is not practical to measure it at sea, and it changes with the draft of the vessel, with her rolling and pitching and as she rides the waves and drops into the troughs. Changes in draft are caused by the consumption of water, fuel, and stores, and may be allowed for by assuming a linear change from port to port, where the draft can be accurately read. The *Carnegie's* draft changes about 1.5 feet during a long passage. As to the ship's rolling and pitching, it is most probable that observations for dip of horizon are never made on the *Carnegie* when she is inclined as much as 10° to the vertical, since care is taken to make them only on even keel as nearly as can be determined. This precaution

*Pulfrich, C.: Ueber einen Apparat zur Messung der Kimmtiefe, Zs. Instrumentenk., Berlin, 1904, Heft 8, pp. 225-229. Moll, E.: Der Pulfrich'sche Kimmtiefenmesser, Hansa, Hamburg, 1906.

was also taken on the *Galilee*. The error in the height caused by an inclination of 10° is 0.3 foot for a height of 24 feet on even keel, and would cause an error less than 0'.1 in the deduced refraction. An error of this size is not likely to occur as one can estimate even-keel position closer than 10° , but errors caused by the rolling and pitching of the vessel will always be in the same direction and can not be entirely eliminated by the mean of many observations.

As the ship rides the waves and drops into the troughs of the sea, the vertical height of the instrument above mean sea-level changes. The visible horizon is delineated as a straight line by the *crests* of the distant waves, if the sea is not too high and irregular. *Accordingly, observations are made only when the vessel rides the waves, on the supposition that the waves are all of the same height and that the instrument will be raised a like amount.* This precaution, however, does not eliminate the whole error, for when the vessel rides the waves, her load water-line is not tangent to the crests of the waves, but always below them. The adopted height, therefore, is too high by the vertical height of the waves above the load water-line.

Observations on the *Galilee* were made by one observer, using dip-measurer No. 4048. Two readings were always made, sometimes 4, 6, and 8, one-half with instrument erect, the other with inverted position. Those made on the first three cruises of the *Carnegie* were obtained with the same instrument (No. 4048) by different observers. Another instrument, No. 4031, was courteously loaned by the United States Coast and Geodetic Survey during the first two passages of the fourth cruise, after which it was replaced by instrument No. 5490. Every determination of the dip-of-horizon on the fourth cruise of the *Carnegie*, therefore, is the result of 2 instruments, and observers were changed every passage or every two passages.

The *data recorded* include the date, latitude, longitude, approximate local time, height of instrument above sea, aspect or definition of the horizon, wind direction and force, air and water temperature, barometer reading, the directions sighted, cloud notes, and direction of the Sun.

In the adjustments that have been made only those observations were used that were obtained under good conditions of the horizon. In the last few years German investigators of the refraction of the horizon have introduced a temperature coefficient in the adjustment of their observations. The temperature of the air can be measured on the ship, but there is no means of measuring the temperature of the air in contact with the sea at the horizon, so it is assumed that the temperature is the same as the surface of the water at the ship. Both temperatures as ordinarily observed may be subject to errors resulting from the methods used. The water temperature is obtained by immersing a thermometer in a bucket of sea water immediately upon hauling it aboard. This is a rather crude procedure, but more precise methods are not likely to give better results in the adjustment until larger systematic errors are eliminated.

The *Galilee* observations, and also those of the fourth cruise of the *Carnegie*, were adjusted to Koss's equation,* which for a constant height of eye, may be written

$$D - D' = x + y (t_a - t_w)$$

The results are given in the original paper.

The adjustments of the observations of first, second, and third cruises of the *Carnegie* were deferred, pending the result of the adjustment of the fourth cruise, since the observations on this cruise having been made with two

*Meyer, H.: Kimmbeobachtungen, Ann. Hydrogr, Berlin, v. 34, Heft 9, 1906, p. 438.

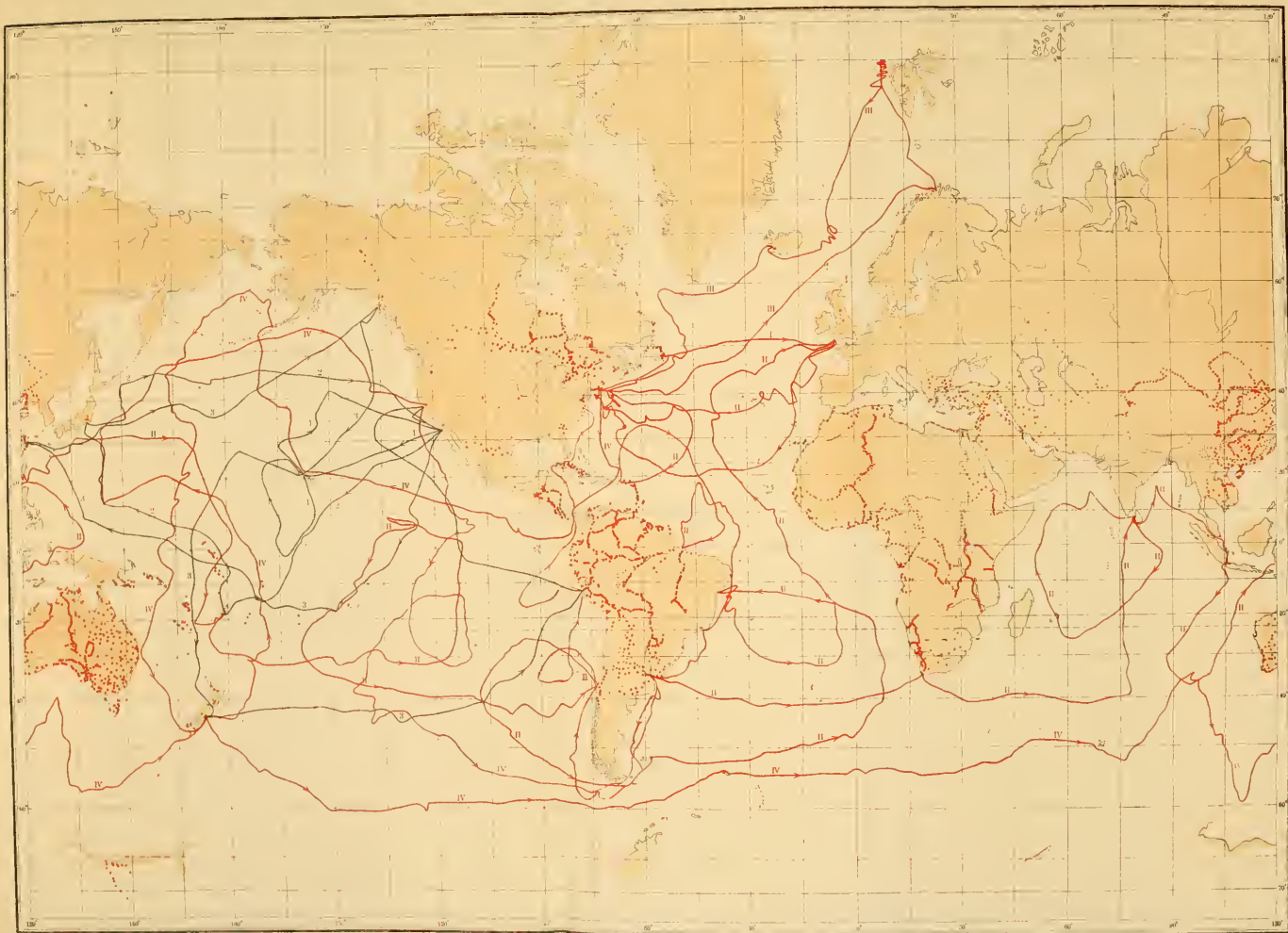
instruments with frequent changes of observers might indicate some improvement in methods of observations or adjustment.

The following conclusions are drawn:

1. The dip-of-horizon tables in common use which ignore air-water temperature-differences are sufficiently accurate for the navigator.

2. Extraordinary values may possibly occur in certain regions, where one should be ready to detect them either by observing stars in different azimuths or by special instruments or special attachments to the sextant. Even if the direction of the abnormal value is uncertain, the knowledge of its existence is a factor of safety.

3. If aerial navigation across the oceans is eventually realized, and astro-nomic methods are used, then simple means of measuring the dip-of-horizon might be desirable if not absolutely essential.



Map showing the Magnetic-Survey Work of the Department of Terrestrial Magnetism during the Period 1905-1918 (October).

(Black lines show the cruises of the *Galilee*, and red ones, those of the *Carnegie*. Red dots show the land stations.)

ARCHEOLOGY.

Morley, Sylvanus G., Santa Fe, New Mexico. *Associate in American Archeology.* (For previous reports see Year Books Nos. 13, 14, 15, and 16.)

The Central American expedition did not return to the United States during 1917, but remained in the field until the end of May, 1918. Throughout this period the personnel of the staff continued the same: Mr. Morley as director and Mr. John Held, jr., as artist. During the Yucatan trip, Dr. Thomas Gann, of Belize, accompanied the expedition as a collaborator, having filled a similar position with the 1916 expedition.

The itinerary of the expedition may be divided into three parts or trips, as follows: (1) A reconnaissance of the Mosquito Coast of Honduras and Nicaragua in September and October 1917. (2) An examination of all archeological sites in the peninsula of Yucatan known to have hieroglyphic inscriptions, in February, March, and April 1918. (3) A trip to the ruins of Palenque in the state of Chiapas, Mexico, in May 1918. It may be noted also that Mr. Morley was present during the earthquake-shocks of December 25, December 29, and January 3, which destroyed Guatamala City, and he assisted in the relief work there.*

The reconnaissance of the Mosquito Coast was undertaken primarily to establish how far eastward along the Atlantic littoral of Central America Maya esthetic influences may have extended, and it was a continuation of the work carried out in the summer of 1917, when the eastern frontier of actual Maya empire was somewhat definitely fixed as the Chamelecon Valley in Honduras.†

At Tela, 35 miles east of the mouth of the Chamelecon River, a beautiful clay head of purest Maya type was found, together with some fine flints and smaller objects. Further excavation, however, would be necessary here before it could be determined whether this head was of local origin, or whether it had been brought in by trade from farther west.

One hundred miles farther east, at Trujillo, and on the Rincon Peninsula, several sites were visited through the courtesy of Mr. H. D. Scott, superintendent of the Trujillo Railroad. These consist of deposits of potsherds, among which incised and modeled wares predominate, handles with animals' heads, fragments of tripod bowls, etc., and a few tubular jade beads, the pottery being distinctly inferior to the beautiful painted ware of the Ulua Valley sites, which are themselves just west of the area of actual Maya dominion as established last year. One of these deposits on the right of way of the

* See "The Guatemala earthquake," by S. G. Morley. *American Museum Journal* for March 1918, vol. xviii, No. 3.

† See Year Book No. 16, pp. 288-289.

Trujillo Railroad, in a borrow-pit near the Aguan River, was fully 10 feet below the present level of the ground, underneath a stratum of alluvial soil laid down by the river in one or more of its many wanderings over the flood-plain. Similar objects have been found on the adjacent Bay Islands, notably at Ruatan and Guanaja, and it seems probable, from the preliminary examination, that this part of the coast and the adjacent islands may be assigned to one and the same archeological province, the culture of which was certainly inferior to that of the Maya and probably of subsequent origin as well.

East of the Aguan River no sites were found, although such may possibly exist in the dense bush behind the beach. From this point eastward, moreover, the character of the country begins to change; the mountains draw away from the shore-line and finally disappear altogether, and there commences a series of shallow lagoons separated from the sea only by a low sandy strip of land. These and the surrounding marshes mark the edges of the great deltas of the Patuca and Wanks Rivers, and they were unadapted to the development of a high culture.*

The present inhabitants of this region are the Miskito Indians, a degenerate mongrel tribe in which Carib and possibly other strains appear. They are a simple fishing people, living in thatched huts along the banks of the lagoons and water-courses, with crude arts and crafts, among which stone carving is not included.

There are traditions of a more cultured tribe, the Sumus, who formerly occupied the region, but who long ago were driven back into the less desirable interior by the Miskito. Remnants of these older inhabitants of the littoral are still to be found several days' journey up the Patuca and Wanks rivers of eastern Honduras and northern Nicaragua.

It may be stated with reasonable assurance, although final proof must await further exploration and excavation, that proceeding eastward along the coast-plain evidences of high cultural activity fall off rapidly once the Ulua Valley is left behind; also, that the Maya civilization proper does not seem to have exerted much influence east of this same valley.

The second trip, to the peninsula of Yucatan, was by far the most important of the year, and the results obtained, through the discovery of the system of dating used in the northern cities, promise to shed a flood of light upon the little-known chronology of the New Empire. It has long been recognized that, after the Maya migrated northward from Guatemala and Honduras during the sixth and seventh centuries after Christ, into the peninsula of Yucatan, along with many another custom and practice, their system of recording

*Stone carvings of grotesque animal heads reported to have come from a site 5 to 6 days' journey up the Black River, just east of the Aguan River, were examined at Rincon. These are quite un-Mayan in character and suggest a local intensive development of stone-carving rather than an extensive distribution of the technique.

dates also underwent considerable modification. The extraordinarily accurate Initial Series, for example, by means of which one day could be distinguished from any other in a period of 374,143 years, which had been so prevalent in the south, practically disappear in the north. Of the 150 odd Initial Series known, only 3 are found in Yucatan. Not only Initial Series, but all the other kinds of texts, become very much scarcer in the north. Indeed, in the whole peninsula there are only 12 sites known having as much as a single inscription, as compared with thrice that number in the south; and the whole content of these few constitutes less than 3 per cent of the *Corpus Inscriptionum Mayarum*.

Because of this scarcity of material—hardly offset by the few manuscript chronicles (the Books of Chilán Balam) that have come down to us—and because of our lack of knowledge as to the method of dating used, it followed that we knew much less of Maya history during the New Empire (600 A. D. to 1541 A. D.) than during the Old Empire (100 B. C. to 600 A. D.).

The immediate object of the second trip, therefore, was an examination of all known Yucatan sites having inscriptions, together with a first-hand study of the original texts, in the hope that some of this obscurity might be cleared away. The sites visited and their respective locations will be found on figure 1.

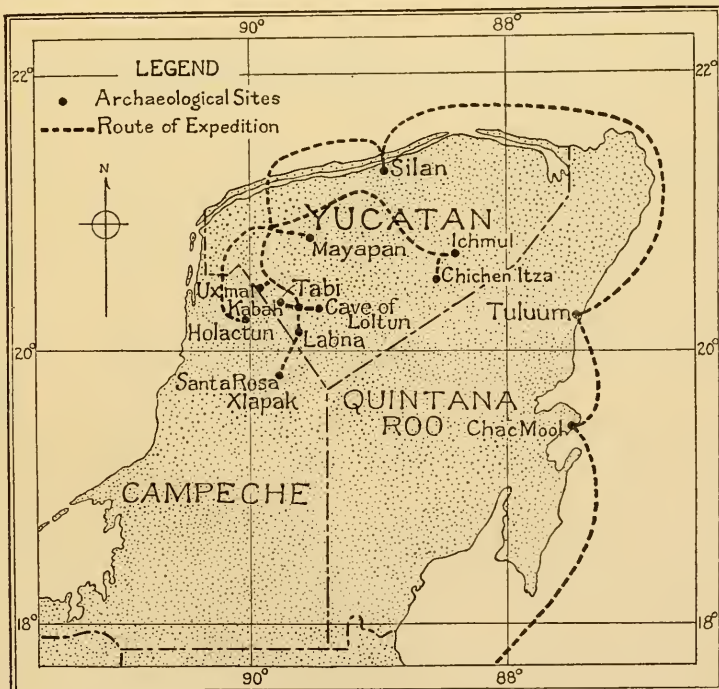


FIG. 1.—Map showing itinerary of the 1918 Central American Expedition in the Peninsula of Yucatan. All sites shown above, with the exception of Chac Mool on the east coast, have hieroglyphic inscriptions.

The results of this investigation were most promising—no less than the discovery of the system of dating used in the New Empire, as noted above. This was found to be a kind of Period Ending dating, and its discovery was made possible by the decipherment of the so-called “winged-Cauac” glyph, which proved to be another variant of the tun sign. Mr. Morley had previously shown that the “winged Cauac” had this meaning in the hotun sign;* and its extension to a more general use in Period Ending dating with coefficients other than 5, as already noted in the case of the hotun sign, was a logical development of Maya chronological practices.

The system was variously employed, the several methods in use depending for their varying degrees of accuracy upon the number of factors present. The simplest is merely the record of a given day falling in a given tun—for example, the day 6 Kan in Tun 9. As every Tun 9 contained one day 6 Kan, and some two such days, and as a Tun 9 recurred every 19.71 years, this method was not very accurate. Happily it does not seem to have been used much, occurring only once in the 16 cases under observation.

The commonest method (being used in half of the cases) is the record of a given tun and the day upon which it ended, as for example Tun 13 ending on the day 2 Ahau. Such a date could not recur fulfilling all the given conditions until after a lapse of 256.26 years. As most of the New Empire sites were not founded until after 950 A. D., and at the most were occupied less than 500 years, it is never necessary in such cases to distinguish between more than two possible readings, and usually only one is historically probable.

By the addition of the day of the month to the above method, as Tun 11 ending on the day 2 Ahau 18 Xul (a date found in the Temple of the High Priest's Grave at Chichen Itza, see fig. 2), accuracy within a far greater stretch of time was secured, no less indeed than within a period of 18,707 years.

A third method, which occurs in 6 out of the 16 cases, is far more accurate than even the preceding. It involves the use of a Calendar Round date with a given tun, ending on a given day. For example, 10 Ix 17 Pop falling in a Tun 17 ending on the day 12 Ahau. Such

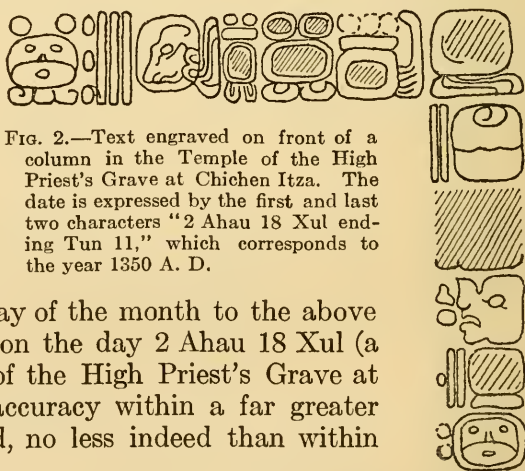


FIG. 2.—Text engraved on front of a column in the Temple of the High Priest's Grave at Chichen Itza. The date is expressed by the first and last two characters “2 Ahau 18 Xul ending Tun 11,” which corresponds to the year 1350 A. D.

* The Hotun as the principal chronological unit of the Old Empire. S. G. Morley. *Proceedings of the Nineteenth International Congress of Americanists*, Washington, D. C., 1915, pp. 195–201.

a date can not recur, fulfilling all the given conditions, until after the lapse of 243,193 years. An example of this kind is given in figure 3, which shows the inscription from the north sides of the rings in the Ball Court at Uxmal. Although both of these texts are fragmentary, enough remains of each to permit its decipherment, the dates of both being the same.*

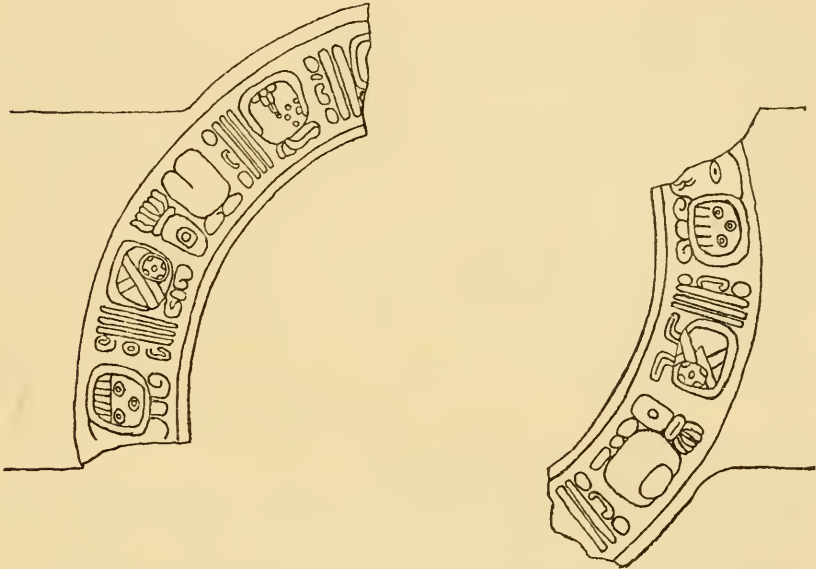


FIG. 3.—Text engraved on sides of the rings of the Ball Court at Uxmal. The same date is recorded upon each ring "10 Ix 17 Pop in Tun 17 ending on the day 12 Ahau," which corresponds to the year 1277 A. D.

A final modification of this last method is seen on the lintel from the north chamber of the western range of the Monjas Quadrangle at Uxmal, where not only the particular tun in which the date fell is given, but the particular katun as well. See figure 4, where 5 Imix 19 Kan-kin is declared to have occurred in Tun 18 of Katun 13. By the addition of this last factor, accuracy within a period of 374,143 years was achieved. The more factors present, the more exact became the resulting date until the extreme accuracy of the Initial Series is equaled by this last method.

Although much remains to be done in working out the details of the new system, already it has been possible to decipher some new dates at

*These two inscriptions may record a very important fact in New Empire chronology. It will be noted that while the corresponding day remains the same in each, *i. e.*, 10 Ix, on the left ring the month is apparently 16 Pop, and on the right ring it is 17 Pop, *i. e.*, a shift of one day in the month coefficient. But this is precisely the degree of shift that occurred between the month coefficients of the Old Empire texts and the very late Books of Chilán Balam. In the Old Empire, Ix has a corresponding month coefficient of 2, 7, 12, and 17, while in the Books of Chilán Balam it has 1, 6, 11, and 16. These two inscriptions, apparently recording the same date with this single slight difference, may possibly commemorate the fact that upon this date this important change was effected at Uxmal.

different sites. These are given below, with the corresponding approximate equivalents in Christian chronology:

Site.	Building.	Date in Maya Era.		Corre- sponding date in Christian Era.
Chichen Itza	Temple of the Two Lintels. . . .	11. 7.12.16.18	9 Eznab 11 Yax..	1107 A. D.
Do	Temple of the High Priest's Grave.	11.19.11. 0. 0	2 Ahau 18 Xul...	1350 A. D.
Do	Temple of the Owl (lintel)	12. 2.13. 0. 0	1 Ahau 13 Ceh...	1411 A. D.
Uxmal	The Ball Court.	11.15.16.12.14	10 Ix 17 Pop.	1277 A. D.
Do	Monjas Quad. E. range N. room.	11.12.17.11. 1	5 Imix. 19 Kankin	1219 A. D.
Holactun . . .	Temple of the Initial Series. . . .	11. 2. 8. 4. 9	7 Muluc. 17 Tzec.	1012 A. D.
Do	Temple of the Initial Series. . . .	11. 2.13. 0. 0	2 Ahau 8 Yax. . . .	1017 A. D.

In addition to the foregoing dates recorded in the new system, several others recorded either as Period endings, or Calendar Round dates, or in the *ukahlay katunob*, were deciphered elsewhere.

Period Ending dates:					
Chichen Itza	Temple of the Initial Series.	Tun 10, 2 Ahau	10.2.10.0.0	2 Ahau 13 Chan	626 A.D.
Tulum	Stela 1	Tun 10, 7 Ahau	10.6.10.0.0	7 Ahau 18 Yaxkin	699 A.D.
Calendar Round date:					
Silan	Stela 1	7 Muluc 2 Kayab			
U Kahlay Katunob:					
Mayapan	Stela 9	Katun 10 Ahau	12.4.0.0.0	10 Ahau 8 Uo	1438 A.D.
Cave of Loltun		Katun 3 Ahau	12.1.0.0.0	3 Ahau 18 Kayab	1379 A.D.

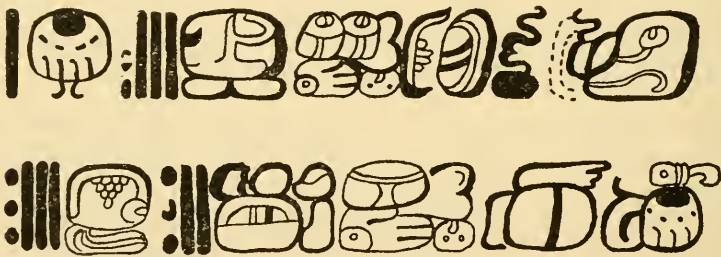


FIG. 4.—Text painted on a capstone in the Western Range of the Monjas Quadrangle at Uxmal. The date is expressed by the first two characters in each line “5 Imix 19 Kankin in Tun 18 of Katun 12,” which corresponds to the year 1219 A. D.

The true date of the Temple of the Initial Series at Chichen Itza is 10.2.10.0.0 2 Ahau 13 Chen, which makes it conform with the hotun hypothesis mentioned elsewhere. Previously this had been regarded as being 10.2.9.1.9 9 Muluc 7 Zac, *i. e.*, the Initial Series on the under side of the lintel. The contemporaneous date, however, is doubtless that recorded on the front of the lintel and is as given above.

Through the accidental discovery of an important missing fragment of the Tulum stela, it has been possible to date that monument as 10.6.10.0.0 7 Ahau 18 Yaxkin—that is, just one cycle later than its Initial Series 9.6.10.0.0 8 Ahau 13 Pax. That this Initial Series

could hardly have been the contemporaneous date of the monument was noted in Year Book No. 15, p. 339, and elsewhere;* but the discovery of this fragment, which fits at the bottom of the inscription, gives a more satisfactory reading. Fortunately this important monument was not lost in the destructive hurricane of October 1916, as previously reported.†

Following Bishop Landa's statement that there were hieroglyphic monuments at Silan near the north coast,‡ the expedition visited this village and found fragments of two stelæ, of which one had the Calendar Round date given above. This is but another of the many instances of the remarkable reliability of Bishop Landa's statements, which have been substantiated at every point by modern investigations in this field. The Mayapan date is from the stela found by Abbe Brasseur de Bourbourg, while digging at the site in the sixties of the last century. It is another corroboration of Bishop Landa, who had described hieroglyphic monuments here three centuries earlier. It is not improbable that this monument was the last katun stone to be erected at Mayapan, since the city was destroyed and abandoned before the expiration of the next 20-year period, *i. e.*, Katun 8 Ahau, when the next stone would have been erected.

One large new site was discovered on the east coast of the Peninsula, between Ascencion Bay and Espiritu Santo Bay. It is about half as large as Tulum and was named Chac Mool, after an heroic-sized Chac Mool statue in stucco reclining under the arch or covered gateway leading to the principal temple.

The most important result of the year, however, was the discovery of the system of dating employed in the New Empire cities, the fundamental significance of which, in the study of Maya chronology, will increase in importance as more and more painted capstones, texts, and inscriptions are brought to light.

The third and last trip of the season to the ruins of Palenque in northern Chiapas yielded little new material. Palenque has been more extensively visited than any other Maya site and its architecture and hieroglyphic inscriptions have been more adequately published.§

Two new Initial Series were found, both in stucco; one on the left-hand pier of the façade of the Temple of the Sun, and the other on the back wall of the outer chamber of the Temple of the Beau Relief. Unfortunately both were entirely destroyed save for their introducing glyphs, and decipherment was impossible.

The large human statue which formerly stood in front of the Temple of the Cross, but which now lies on the southern slope of the substructure

*"The ruins of Tulum, Yucatan," by S. G. Morley. *The American Museum Journal* for March 1917, vol. xvii, No. 3, pp. 109-204.

†*Ibid.*, p. 194, note 1.

‡*Relacion de las Cosas de Yucatan*, Diego de Landa, Paris, 1864, p. 52.

§See *Biologia Centrali Americana*, or contributions to the knowledge of the flora and fauna of Central America and Mexico. Section on Archeology. A. P. Maudslayi, vol. iv, text and plates.

ture, has a single glyph carved upon its front. This is quite clearly the day 8 Ahau and in all probability denotes the katun ending 9.13.0.0.0 8 Ahau 8 Uo. This is also the latest date on the tablet of the Foliated Cross in the temple of the same name nearby, and on the tablet in the Temple of the Inscriptions across the stream, and is possibly to be interpreted as indicating that these three temples were all dedicated on the same day.

In spite of certain architectural evidence to the contrary, it seems fairly clear from the seven or eight dates now known at Palenque, that the city was at its zenith about 9.13.0.0.0 and not a hundred years later, as has been suggested. Indeed 9.13.0.0.0 is the latest date that has yet been found there. Beautiful as the Palenque sculptures are—possibly the best in the whole Maya area—their excellence may probably be ascribed to the superiority of the sculptural media, stucco or a very fine-grained limestone, rather than to a later period of origin, and the city itself had probably already reached the zenith of its esthetic development before the beginning of the Great Period in 9.15.0.0.0.*

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The Index Medicus for 1917 represents 682 pages of bibliographic material, with an index of 134 pages. The restricted size of the annual volume is a measure of the response to national crises by physicians and scientists and of the difficulty of obtaining foreign medical periodicals. Transactions of medical societies and congresses in normal times furnish a substantial quota of references and the cancellation or postponement of these meetings is reflected in a reduced quantity of medical literature. Continued preponderance of war literature is manifest throughout and has necessitated the introduction of additional subject rubrics under the section of Military Medicine. A War Supplement, constituting a classified bibliography of medico-military literature, has also been issued. It embraces some 12,000 items in 260 pages and furnishes references to subjects of military interest from January 1914 to December 1917. A new type-page has been designed to facilitate more ready reference.

*A correction should be noted here in the report of the previous year's work. On p. 288 of Year Book No. 16, attention was called to the discovery of the ruins of Los Higos in the Chamelecon Valley, Honduras, through information derived from Mr. S. K. Lothrop, of Harvard University, and Mr. Basil Booth, of Guatemala City. Credit for this discovery, however, it has been subsequently ascertained, belongs instead to the well-known Central American traveler, E. G. Squier, who visited this site as early as 1850, and who seems to have published his first account thereof in Frank Leslie's Magazine for April 1883; "Ancient laborers and princes of Grand Chimú and New Granada." E. G. Squier, Frank Leslie's Magazine, vol. xv, No. 4, April 1883, pp. 468–480. Although he was unable to read the hieroglyphic inscriptions there, his visit having antedated by more than 30 years the first successful attempts at decipherment by Professor Ernst Forstemann and J. T. Goodman, Squier's priority of discovery remains unquestioned and any credit arising therefrom belongs to him; acknowledgement of which is made here.

BIOLOGY.

Morgan, T. H., Columbia University, New York. *Study of the constitution of the germ-plasm in relation to heredity.* (For previous reports see Year Books Nos. 15, 16.)

The following report covers the work of T. H. Morgan, C. B. Bridges, and A. H. Sturtevant for the year 1917-18 on the constitution of the hereditary materials of the pomace fly, *Drosophila melanogaster*.

Studies of the linear order of the genes in the chromosomes have continued to occupy the first place in our work, because *Drosophila* surpasses all other material for the analysis of this fundamental problem of genetics. In our report for the first chromosome (Carnegie Inst. Wash. Pub. No. 237) the location of 33 genes was given. Twice as many more are now known to us, the data for which will be ready for publication before long. A report now in press (Carnegie Inst. Wash. Pub. No. 278) gives the data bearing on the location of 23 genes in the second chromosome. An equal amount of data relative to as many more mutant characters is being written up. The material needed for the presentation of the third-chromosome data, including the description of some 50 mutants, is also being prepared for publication.

Complications have appeared in the localization problem, owing to the discovery in *Drosophila* of specific variations in crossing-over caused by definite cross-over genes (see especially Carnegie Inst. Wash. Pub. No. 278). Only a little has hitherto been published on this subject, although we now know the effects of seven such genes in considerable detail, besides having fragmentary evidence on others. Two of the seven are in the first chromosome, three are in the second chromosome, and two are in the third. One of the third-chromosome cross-over genes has, besides its effect on the third chromosome in which it is situated, a very marked effect upon the second chromosome as well.

There is in *Drosophila* an unique opportunity for the examination of this important subject of linkage variation, on account of the completeness with which the normal relations are known and the advantage of the closeness of analysis afforded by the very numerous mutant loci.

Aside from its intrinsic interest, the localization of a large number of genes has furnished an opportunity for a successful analysis of the classic problem of selection. A. H. Sturtevant has just brought through the press the result of a year's work on this problem (Carnegie Inst. Wash. Pub. No. 264). C. B. Bridges has sent to press a detailed account of the specific modifiers of eosin (Jour. Exp. Zool.). T. H. Morgan has in press a paper on genes that modify a dominant character called "notch" wing (Carnegie Inst. Wash. Pub. No. 278).

During the last eight years many gynandromorphs of *Drosophila* have appeared. This material has been brought together and a general

theory to account for the origin of gynandromorphs and mosaics has been proposed (Carnegie Inst. Wash. Pub. No. 278).

The origin of mutations is one of the most difficult and perplexing problems engaging the attention of biologists. Our material is slowly contributing toward the solution of this problem in several directions. For example, the reappearances of certain "recurrent" mutations is being carefully watched and parallels between mutations in *Drosophila* and those in other species are being followed out. Some indications of the nature of the mutative process are also afforded by the numerous cases of multiple allelomorphs and "deficiencies."

In the course of the work new openings are continually appearing, some of which are as fruitful as the main lines of work engaging our attention. For example, several ways in which chromosome groups may undergo evolution have appeared; through "non-disjunction" whole chromosomes may be added or lost; by "duplication" sections of chromosomes may be added; and by "deficiency" sections of chromosomes may be lost.

The work on a hereditary tumor in *Drosophila* (lethal 7) has been continued by Miss Stark. The first paper is now about to appear in the Journal of Cancer, and a second is ready for the press.

The possible influence of radium on the hereditary material of *Drosophila* is undergoing further investigation.

The high female ratios (excess of females) that occasionally appear have been analyzed and found due to sex-linked lethals. A high male ratio, that has recently appeared, promises to give a clue to the solution of this problem also.

A further attempt to cross species of *Drosophila* having different groups of chromosomes has been made, especially by artificial impregnation, but so far without success.

During the past year approximately 40 new mutations have been found, which have provided us with means of controlling the behavior of several chromosome regions about which our knowledge was formerly insufficient. Several of these mutations are of such a character that they add greatly to our working material, enabling us to attack both old and new problems with greater success. We are now in position to supply to others not only the method but also the material for the solution of questions that could not heretofore be handled by exact methods. At more than thirty institutions teachers are using our material for demonstration of the principles of heredity to students, and many of them are conducting researches of their own on selection and other phases of heredity. Some of these institutions are now secondary centers of distribution, so that the material is rapidly becoming widely used. The maintenance of this valuable stock is becoming something of a burden at headquarters.

CHEMISTRY.

Noyes, Arthur A., Massachusetts Institute of Technology, Cambridge, Massachusetts. *Researches upon (1) the properties of solutions in relation to the ionic theory, and (2) the determination of the atomic structure of crystalline substances by X rays.* (For previous reports see Year Books Nos. 2-16.)

The work described in last year's report on the potentials of the copper cuprous-chloride and bismuth bismuth-oxychloride electrodes, carried out with the assistance of Mr. Ming Chow, has been published.

A thorough investigation has been made by Dr. C. L. Burdick and Dr. E. S. Freed of the equilibrium conditions, at temperatures from 0° to 75°, of the reaction $3 \text{NO}_2 + \text{H}_2\text{O} = 2 \text{HNO}_3 + \text{NO}$, by determining the pressures of the two nitrogen oxides which are in equilibrium with nitric-acid solutions of various concentrations. This has thrown much light on the problem of the absorption of nitrous vapors on a large scale and the results are likely to be of importance in connection with the war needs for manufacturing nitric acid.

The research on the determination of crystal structure, referred to in the last report, has been continued by Dr. Duncan A. MacInnes with the aid of Messrs. James A. Beattie and Arthur L. Davis. The work has been directed mainly to developing a method by which the intensities of the reflections can be accurately measured. In determining the structures of simpler crystals comparatively rough measurements of the intensities suffice, but in studying the more complicated atomic structures accurate determination of these intensities becomes a matter of importance. Up to the present the intensities have been assumed to be proportional to the deflections of the leaf in the electroscope of the Bragg apparatus. This method can not give correct results unless, among other things, the source of X rays is constant. To eliminate this difficulty a modified Bragg apparatus has been devised, in which the X-ray beam strikes a second, reference, crystal, and the reflected beam from this crystal affects a second electroscope. The intensity of reflection of any order from any plane of a crystal can thus be compared with that of the reference crystal. Provision is also made for reproducing the deflections of the electroscope leaves by applying measured electromotive forces, in terms of which the intensity ratios can be expressed.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and simple compounds.* (For previous reports see Year Books Nos. 2-16.)

A part of the time and energy of the personnel of the Wolcott Gibbs Memorial Laboratory was taken, during the earlier portion of the year, by important war work, which does not form a part of this report. Throughout the year several army officers in the Sanitary Corps

worked at the laboratory upon the physicochemical properties of the constituents of cereals, especially glutenin and gliadin, the components of wheat gluten, under the direction of Professor Lawrence J. Henderson. This work included not only scientific study, but also practical application of the results to the process of bread-making and the more effective utilization of wheat substitutes. The physicochemical apparatus and books belonging to the Carnegie Institution of Washington at the laboratory were put at the service of these investigators and enabled them to carry out researches which would otherwise have been impossible and which are leading to highly important results.

Owing to the departure into Government service of most of the other assistants at the laboratory, a smaller amount of work was possible than would otherwise have been accomplished; but several results of interest and significance were nevertheless secured, as follows:

1. REFRACTIVE INDICES OF THE NITRATES OF LEAD ISOTOPES.

With the assistance of Dr. Walter C. Schumb, the refractive index of the nitrate of pure common lead was compared very carefully with that of the nitrate of uranio-lead prepared from the Australian material mentioned in previous reports. The two samples of nitrates were separately recrystallized with care, and finely developed crystals were measured in the Abbe-Zeiss total-reflecting crystal refractometer. A solution of sulphur in methylene iodide having a refractive index of 1.79 was used as the contact liquid and very careful measurements were made of many crystals in varying positions. The refractometer was standardized by means of a polished glass prism possessing an exactly known refractive index which could be verified by the method of minimum deviation. The refractive index of common lead nitrate at 20° was found to be 1.7815 and that of uranio-lead nitrate was found to be 1.7814, each value being a mean of many concordant determinations. Thus the difference in atomic weight shown by the two specimens of lead (the atomic weights are respectively 207.20 and 206.41) has no appreciable effect on the refractive index of the salt—a highly interesting and newly discovered fact.

2. SOLUBILITIES OF THE NITRATES OF LEAD ISOTOPES.

Dr. Schumb assisted also in the following work: The two specimens of lead nitrate which had been purified (crystals of which had been used in the preceding investigation) were investigated with great care as to solubility, using a method described on page 301, Year Book No. 16, with small but convenient improvements. Greater difficulty was found in obtaining an exactly saturated solution than was the case with sodium sulphate, at least 24 hours at perfectly constant temperature being needed in order to obtain constant results. The weighed portions of solution, saturated at 25.02°, were evaporated with excess of sulphuric acid and the sulphate was gently heated at 350° until constant in weight. Four such determinations with ordinary lead nitrate

gave values from 37.33 to 37.36. (average 37.342) grams of nitrate in 100 grams of solution, and nine determinations with uranio-lead nitrate gave values from 37.26 to 37.30 (average 37.280) grams of nitrate in 100 grams of solution. These results are precisely proportional (within the limit of error of experiment) to the different molecular weights of the two samples of nitrate. Expressed in other terms, the molal solubilities of the two samples per 1,000 grams of water are respectively 1.7993 for common lead nitrate and 1.7991 for uranio-lead nitrate. The outcome of this work, then, by finding no appreciable difference in the molal solubility of the different samples of lead nitrate containing isotopes of widely different atomic weights, confirms earlier work upon other properties of these interesting substances. Evidently weight (or mass) is the prime distinguishing feature of the two kinds of lead here studied, as it was in other cases. This work and that described in the preceding section thus afford further support for the hypothesis due to Russell, Fleck, Soddy, and Fajans.

3. PURIFICATION OF GALLIUM BY DISTILLATION OF THE CHLORIDE.

With the help of Mr. W. M. Craig, a new method for the purification of gallium salts was worked out in some detail. This rests upon the convenient fact that gallium trichloride sublimes and distils at a low temperature, whereas the other chlorides likely to be associated with it are much less volatile. The method rested, therefore, upon fractional distillation, at first in a stream of chlorine and afterwards in a vacuum, of impure gallium chloride. The apparatus was a complex affair, in which gallium could be first burned in pure dry chlorine and then subjected to distillation either in pure chlorine or nitrogen or in a vacuum, the whole being fused together without rubber connections and scrupulously dried. The gallium was provided through the great kindness of Mr. McCutcheon, of the Bartlesville Zinc Company, Blackwell, Oklahoma, to whom grateful thanks are due. Three successive distillations of the trichloride of gallium were made in chlorine at 220° to 230° C., three more at about 175° (the melting-point of gallium dichloride), three in nitrogen at 90° to 110°, and five *in vacuo* at 65° to 80°—fourteen in all. The resulting product showed no trace of any other substance in its spark spectrum when examined with great care in a Hilger wave-length spectrometer. Although this research did not reach a final stage, and much more remains to be done in order that perfect certainty may be attained, nevertheless the outcome must be regarded as promising in pointing toward an adequate and convenient method of separating gallium from other metals. The analysis of the resulting material is discussed in the following section.

4. PRELIMINARY DETERMINATION OF THE ATOMIC WEIGHT OF GALLIUM IN THE CHLORIDE.

Three fractional samples of the chloride discussed in the previous section were analyzed by Dr. J. Sameshima, using the usual methods

employed in Harvard University in order to make a preliminary determination of the atomic weight. The samples were small and for various reasons the results can not be considered as anything more than preliminary, but the outcome is, nevertheless, worth recounting. In the last and best determination 0.43947 gram of gallium chloride (weighed *in vacuo* in a sealed glass tube) yielded 1.07087 grams of silver chloride, having required 0.80587 gram of silver for complete precipitation. The atomic weight of gallium computed from these two sets of data are respectively 70.09 and 70.11; the concordant results indicate a value somewhat higher than that usually accepted for gallium, but near enough to show that the chloride was at least not far from being pure and that the whole proceeding is capable, when employed with larger quantities of material and with the experience already gained, of affording an accurate evaluation of this atomic weight. At the conclusion of the war it is hoped that Mr. Craig will be able to complete the investigation.

5. PURIFICATION OF GALLIUM BY ELECTROLYSIS.

With the help of Mr. Sylvester Boyer, various other methods for purification of gallium were studied in detail. The method recommended by various authorities, of separating gallium from indium by means of the different solubilities of the hydroxids in caustic alkali, was tested without great success. The separation was found to be so incomplete that a considerable percentage of indium remained in the gallium, at least under the conditions used in our work, and it seemed clear that this difference in solubility is not enough to effect a complete separation. Much more promising results were obtained by the electrolytic method. Gallium occupies a place in the electrolytic series between indium and zinc. It is far less easy to deposit than indium, but much more easy to deposit than zinc. By carefully regulating the hydrogen-ion concentration and current density it was possible to deposit practically all of the indium with only a little gallium, and thereafter most of the gallium could be separated in a slightly acid solution without the appearance of an important amount of zinc. Gallium obtained in this way, from material which had previously been purified by the hydroxide method, melted at a temperature as high as 30.8° , a higher melting-point (indicating a purer substance) than is recorded anywhere in the literature. The metal obtained by the hydroxide process, without electrolysis, melted at a temperature as low as 26.9° . Time has as yet been lacking for making complete spectroscopic and other tests of this material in order to confirm its complete purity, but enough has been done to show that this method is very satisfactory and convenient. Because of its obvious advantages it must have been employed before by others, but no mention has yet been found of it.

6. COMPRESSIBILITY OF GALLIUM IN SOLID AND LIQUID CONDITION.

Having thus prepared gallium of substantial purity, Mr. Boyer proceeded to determine its compressibility, both in the solid and in the liquid condition. This was an interesting problem, since comparatively few substances have been measured in both states. Moreover, gallium has the remarkable and rare property of occupying more volume in the solid than in the liquid condition. The determination of the compressibility was desirable in order to add to the long list of elements already determined at Harvard under the auspices of the Institution. The apparatus and principle of the method was essentially similar to that employed in other cases, but a new difficulty was encountered. As in the case of other metals, the gallium could not, of course, be allowed to come in contact with the mercury in the piezometer, but, on the other hand, it could not be conveniently solidified in any tube under such an inert liquid as toluene without bursting the tube. After many more or less satisfactory devices had been tried, the best results were obtained by first solidifying gallium and then placing a cylinder of the solidified metal in a slightly larger short test-tube, just fitting it, and capping this with another similar slightly larger test-tube under the inert liquid. Twenty-three grams of gallium were used in this work and the compressibility was found to be 2.09×10^{-6} , placing gallium precisely on the curve joining the other compressibilities in the graph representing the periodic relation of this property to atomic weight. The compressibility of gallium containing several per cent of indium as obtained by the hydroxide method was found to be somewhat less (1.97×10^{-6}). Liquid gallium was determined not only in this apparatus, but also in one similar to that used for caesium (Carnegie Inst. Wash. Pub. No. 76, p. 20). The liquid was thus found to have a compressibility of 3.97×10^{-6} , a value almost exactly identical with that for mercury and nearly twice as great as that of solid gallium, although its volume is less. The determination was made at 30° . This confirms the universal experience that solids have compressibilities distinctly less than the same substances as liquids, entirely irrespective of the volumes which they occupy. The most marked case of this kind thus far observed is that of ice.*

7. DENSITY OF SOLID AND LIQUID GALLIUM.

With the assistance of Mr. Boyer, the densities also of solid and liquid gallium were determined. These data have especial interest because the expansion of gallium on freezing has been attributed by some investigators to impurity. In the first place, careful determinations were made by means of a pycnometer for solids (Richards and Wadsworth, Jour. Amer. Chem. Soc., 38, 222, 1916) of the density of the impure material containing some indium, in the solid and liquid condition, the values being found respectively 5.975 and 6.166. Sub-

*Richards and Speyers, Jour. Amer. Chem. Soc., vol. 36, 491, 1914; Carnegie Inst., Wash.; Year Book No. 8, p. 221, 1909.

sequently, when the purest material had been obtained, the determinations were repeated with equal care, giving values 5.885 and 6.081 respectively. Evidently indium had produced no essential effect upon the expansion on freezing. Even if the more carefully prepared gallium was not absolutely pure, it is evident from the outcome, by extrapolation, that the purest gallium must still possess this unusual property.

Several of the investigations of previous years were prepared for publication and are recorded on page 36 of this volume.

Sherman, H. C., Columbia University, New York. *Continuation of the chemical investigation of the amylases.* (For previous reports see Year Books Nos. 11-16.)

During about one-third of the time since the writing of the last report, experimental work upon this research was suspended while the writer, with the approval of the Institution, was engaged upon an investigation of the food-supply of Russia in behalf of the War Council of the American Red Cross. Early in 1918, the laboratory study of the amylases and related enzymes was resumed.

On account of the present importance of the partial substitution of other grains and of potatoes for wheat in our national food economy, the work of the present year is chiefly devoted to a comparative study of the digestibility of wheat, maize, rice, and potato starches. The experience gained during several years' study of the starch-splitting enzymes is thus being brought to bear upon the present-day problem of wheat saving, and the results thus far obtained are favorable to the view that the starches of the principal substitutes for wheat are, under comparable conditions, quite as readily digested as is the starch of wheat itself. When all are purified by the same method and gelatinized by boiling with water in the same manner, wheat, maize, and rice starches appear to be hydrolyzed by enzymes with practically equal facility. Under the experimental conditions thus far investigated, this has been true whether the digestive (hydrolytic) agent were saliva, pancreatin (natural mixture of pancreas enzymes), purified pancreatic amylase, malt extract, purified malt amylase, takadiastase, or the purified amylase of *Aspergillus oryzae*. With potato starch the results are less regular and require further investigation. The cereal starches should also be compared through a greater range of experimental conditions before final conclusions are drawn. For the present we propose to devote our efforts primarily to this phase of the research. Such a comparative investigation of the action of typical amylases and digestive secretions upon starches of different origin has always been a part of our general plan of research and is

now not only of scientific interest, but also immediate economic importance because of its bearing upon the problems of food conservation. The results already obtained, taken in conjunction with the studies of the efficiency of the maize proteins in human nutrition, carried out in these laboratories at the same time, though independently of the grant from the Carnegie Institution of Washington, have already proven useful in support of the movement for a larger use of maize as human food.

Progress has also been made upon two of the problems referred to in previous reports—the influence of hydrogen-ion concentration upon the activity of the different amylases, and the relationship between amylolytic and proteolytic activity in enzyme preparations from the pancreas.

The use of the Clark cell and rocking electrode has resulted in a much sharper definition of the hydrogen-ion optimum for pancreatic amylase than has previously been established and has confirmed our earlier determination of the optimum for malt amylase. As regards the influence of hydrogen-ion concentration upon its activity, the amylase of *Aspergillus oryzae* bears much more resemblance to that of malt than to that of the pancreas. The results of this comparative study are best summarized by means of tables and curves rather than by such discussion as is feasible in the present report.

In the method developed in this laboratory and frequently employed here during the past seven years for the purification of pancreatic amylase, a high-grade pancreatin is extracted with 50 per cent alcohol, the filtrate precipitated with alcohol-ether mixture, and this precipitate dissolved in water and precipitated with absolute alcohol, then redissolved and dialyzed in 50 per cent alcohol containing maltose to retard deterioration, and finally precipitated by adding to the solution an equal volume of a 1:1 alcohol-ether mixture. During the dialysis there settles out in the dialyzing sacs some material which, originally soluble in 50 per cent alcohol, has now become insoluble in the same solvent, apparently as the result of the intervening precipitation in alcohol of higher concentration. This by-product has little if any diastatic power, but shows even higher proteolytic activity than does the final amylase preparation. In fact, it is apparently the most active protease known, and is worthy of much further investigation.

In the course of our attempts to find whether the amylase and protease activities of the final product obtained by the method just outlined are due to separable substances, we have frequently substituted for the usual final step a further fractionation, precipitating first with a mixture of two parts of alcohol to one of ether, after which a second precipitate was obtained by adding more ether. The amylolytic activity of the first precipitate was usually lower than that of the second, but the latter was not more active than our previously

described amylase preparations. The proteolytic activity was higher in the first precipitate. Taken alone, this latter fact would suggest that the usual amylase preparation may be a mixture of amylase and protease, of which the protease is here concentrated in the first fraction; but in this case the second fraction should show a higher concentration of amylase than our usual amylase preparations, which was not the case.

In order to explain the experimental results on the assumption that the proteolytic activity of our purified pancreatic amylase preparations is due to the presence of an admixed protease, it is necessary to make further assumptions to account for the fact that a fractional precipitation which concentrated proteolytic activity in one fraction does not concentrate amylolytic activity in the other. It is possible that a partial separation of amylase and protease may have been accomplished, but that the amylolytic activity of the second fraction suffered deterioration because of the extra manipulation. On the other hand, the facts are equally consistent with the view that the amylolytic and proteolytic activities may be properties of the same substance (analogous to the finding of Osborne and Wells that a single isolated protein may contain more than one antigenic radicle); and that in contact with alcohol this substance tends to undergo a change by which its solubility and amylase activity are diminished and its protease activity increased. This would explain the fact that, among the products here considered, the proteolytic activity is the highest in the fractions least soluble in alcohol, and that when the usual final precipitate was further fractioned it was possible to obtain a product with increased proteolytic, but not one with increased amylolytic activity.

It is planned to continue the investigation of these latter problems in the future, but for the present to give precedence to those phases of the research bearing directly upon food problems which have been rendered urgent by war conditions.

The efficient work of those who have collaborated in these investigations, whether as research assistants or volunteers, is gratefully acknowledged.

Smith, Edgar F., University of Pennsylvania, Philadelphia, Pennsylvania.
Investigations with the elements columbium, tantalum, and tungsten. (For previous report see Year Book No. 16.)

The work on the atomic weight of boron and the atomic weight of fluorine was finished in May and has been issued as Publication No. 267 of the Carnegie Institution of Washington. At present I am engaged upon a study looking to the separation of columbium from tantalum. The first step was a review of all the methods suggested for this purpose. They have not been separated quantitatively by any of the methods used in the past. Two or three new lines have been tried and are promising good results.

ECOLOGY.

Clements, F. E., Tucson, Arizona. *Associate in Ecology*. (For previous report see Year Book No. 16.)

The experimental work of the year has been centered at the Alpine Laboratory on Pike's Peak during the summer. Experiments have also been made at the Desert Laboratory from January to May upon the periodicity of stomata and their relation to transpiration and witing. Vegetation studies have been carried on throughout both these periods in the region about Colorado Springs and Tucson respectively. In addition, two major expeditions have covered a large part of the West in connection with the further investigation of indicator plants and grazing conditions. The first of these traversed Arizona, California, Oregon, Idaho, Utah, Wyoming, and Colorado during May and June; the second occupied the month of September and was concerned chiefly with the Great Plains from Colorado to North Dakota and thence southward through South Dakota, Nebraska, Kansas, Texas, and New Mexico to Arizona.

In both experimental and vegetation work, the principles of synthetic ecology have served as a guide. The chief emphasis has been placed upon quantitative measurements and the correlation of factors and responses, both with plants in communities and with individuals. An especial effort has been made to correlate the various researches with each other and to synthesize the results in such a manner as to permit their application to related fields. It has also been recognized for the first time that animals are a factor of profound importance in all plant associations and a number of quadrat inclosures and exclosures have been installed to measure their effects. The studies at the Alpine Laboratory have been largely in continuation of researches carried on during the past fifteen years, as a consequence of which it has proved possible to complete several of them for publication. Owing to the exigencies of the situation, the major attention during the year has been given to plant indicators, climatic cycles, and grazing research. This has made it necessary to further postpone the completion of the study of succession and reclamation in bad lands. However, opportunity has been found for visiting several new bad-land areas in connection with the work on indicators and climatic cycles. It has also proved possible to organize the work in paleo-ecology with greater definiteness.

FACTOR STATIONS.

As a basis for the interpretation of plant responses and community behavior, a number of stations has been established at Pike's Peak in different formations and at different altitudes. These have been located on the plains, in the foothills, and in the montane and subal-

pine zones. Areas have been fenced against rodents especially, and instruments installed in the short-grass plains at 6,000 feet, and in chaparral and in the pine consociation at 7,000 feet. In the mountains, similar installations have been made in the gravel and half-gravel associates and in the Douglas-fir climax at 9,000 feet. Each station was equipped with recording instruments for temperature, and humidity, and with rain-gages and porous-cup atmometers. Weekly readings were made of the water-content and several series of light readings were obtained. The most striking feature was the use of standard plants to determine the transpiration and rate of growth, as explained in the following paragraph. The quantitative results thus obtained have been used in practically all of the experimental studies indicated below, and some of the details are given in the published accounts of these. While the instrumental data have much value in delimiting the climates and habitats, it seems best not to publish them until they have been obtained for another year or two, when it will be possible to make effective comparison with similar results secured from 1902-1906.

The Phytometer Method, by F. E. Clements, J. E. Weaver, and F. C. Jean.

The publication of Research Methods in Ecology in 1905 was due to the conviction that ecology to progress must become a quantitative science. In the endeavor to accomplish this, practically all the accepted meteorological instruments were employed and a number of new instruments were devised for habitat analysis. During the twenty years that have elapsed since the first quantitative analyses of habitats in 1898, the value of instrumental methods has become generally recognized. As the attention of the ecologist became centered more upon the plant, however, it was found that instrumental data often threw little or no light upon the plant's behavior because of the difficulty of changing from a physical to a biological system. In the hope of remedying this, an endeavor has been made to devise a biological method of measuring habitats by means of standard plants. Batteries of such plants, for which the term "phytometer" is suggested, have been installed at the various factor stations, and three series have been measured during the summer. The plants employed were wheat, oats, sunflower, and raspberry (*Rubus strigosus*), all of which grew readily at the different altitudes. They were grown in the same kind of soil in sealed containers and were protected from rodent damage by fences of wire netting. A record was kept of the water-loss from week to week, as well as of the various physical factors, and the results have been expressed in terms of water-loss in relation to unit leaf-surface and to dry weight, of photosynthate produced per leaf-unit, and in terms of growth. The method promises to be of great value in interpreting climates and soils in terms of plant

behavior and bids fair to relegate analysis by physical instruments to a secondary place. It should find wide application in dry-land agriculture grazing, and forestry, in determining the possibilities of climates and soils, and in definitizing the use of plant indicators. A detailed account of the method and of the results is being prepared for publication.

Photosynthetic Efficiency, by F. E. Clements and Frances Long.

The recent chemical methods of estimating carbohydrates in plants have been somewhat refined and applied to the problem of measuring the food-making activity of plants under natural conditions. Two major lines of study have been followed, one dealing with the same plants under different conditions, and the other with different species under the same conditions. The former has received the chief attention in the field, and it is expected to give more attention to the latter under control conditions during the fall. The standard plants used as phytometers have served to show the photosynthetic behavior of different species in several habitats as well as the efficiency of each species in different habitats. In addition, studies have been made of the photosynthetic activity of ecads growing naturally in sun and in shade and of paired species found in opposite light conditions. An attempt has also been made to determine the rate of carbohydrate production during the day, and its relation to the curve of daily light intensity. Factor readings have been secured in all cases and especial attention has been paid to light intensity and quality. The method is expected to prove of especial value in forestry, where reproduction and growth are largely determined by the light intensity. It should also prove useful in permitting comparisons of the food-making efficiency of varieties of crop-plants, as well as of native species.

Behavior of Stomata, by G. V. Loftfield.

This work is in continuation of investigations carried on at the Experiment Station of the American Smelter and Refining Company at Salt Lake City, under Dr. P. J. O'Gara, in 1916. Forty species of crop plants were studied to determine the relation of stomata to the injurious action of smelter fumes upon plant tissues. To accomplish this, it proved necessary to ascertain the behavior of the stomata of both leaf surfaces throughout the day and night. This was done by removing strips of epiderm from the leaf at hourly intervals throughout a 24-hour period and fixing the stomata in absolute alcohol. The strips were mounted and micro-photographed to yield a series of 48 prints, showing the openings of the stomata on both surfaces for every hour of the day and night. At the same time, complete records were taken of the physical factors by means of recording instruments.

Finally, the series of prints for several of the most important species, such as alfalfa, potato, and barley, were mounted in a circle to permit ready measurements and comparison of the openings on both surfaces for the 24 hours.

Similar studies were made at the Desert Laboratory on several species of xerophytes and winter annuals. In addition, particular attention was paid to the relation of the stomatal opening to transpiration and to wilting. The annuals were transplanted into uniform soils in pots and were maintained at different amounts of water-content from the minimum to saturation; 24-hour series of strips and transpiration weighings were made of these as well as of plants as they approached and passed the wilting-point. The results of the investigation seem to harmonize the diverging views as to the regulatory action of stomata, since they not only show that species exhibit extreme differences in the daily activity of their stomata, but that the upper and lower epiderms of the same species may also vary greatly. Probably the most important result is that all the species studied with reference to wilting indicated that the stomata had a decisive regulatory action at this time, even in the case of those most passive under less extreme variations in the water relations.

Transpiration of Trees, by J. E. Weaver and Anne Mogenson.

This study has dealt with the transpiration of coniferous and deciduous seedlings out-of-doors during the winter and summer. The experiments were carried on at the University of Nebraska from September to May and at the Alpine Laboratory during June and July. The species employed were *Pinus ponderosa*, *P. banksiana*, *Pseudotsuga mucronata*, *Picea engelmannii*, *Abies grandis*, *Acer saccharinum*, *A. glabrum*, *Ulmus americana*, and *Quercus macrocarpa*. The material consisted of 2- and 4-year seedling conifers and 1-year deciduous seedlings, potted in the same soil in sealed containers. Each battery comprised approximately 10 individuals of each species. The containers were placed on the ground and held in place by a frame 12 inches high, the intervals being filled in with soil. A record of the humidity and of both air and soil temperatures was obtained by means of hydrothermographs. The transpiration was measured by weighing from time to time on a balance sensitive to 0.5 gram under a load of 8 to 9 kg. The winter transpiration of the conifers proved to be exceptionally small, ranging from less than 1/100 to less than 1/200 of that for the autumn per unit area. During the autumn, the daily loss from the conifers was nearly twice as great as that from the deciduous species, with the exception of *Quercus macrocarpa*. The daily loss from the deciduous trees also bore an interesting inverse relation to their water requirements, *Quercus macrocarpa* transpiring nearly twice as much as *Acer saccharinum*. The summer transpiration of *A. saccharinum*

and *A. glabrum* proved to be nearly twice as great as that of the conifers. The results indicate that the conifers studied are more xerophytic than the broad-leaved species during the summer and that the needle habit is practically as efficient as the deciduous one in preventing serious water-loss in the winter time.

Light Measurements, by F. E. Clements.

The study of light intensity and quality has been continued during the summer at various points in the West, and especially at the Alpine Laboratory. Repeated measurements from 1902 to 1912 indicated that the light intensity on high peaks, such as Pike's Peak and Mount Garfield, was scarcely or not at all higher than at points 6,000 to 8,000 feet below. In spite of the fact that this does not conform to the theory, it seems to be readily explained by the low humidity and the absence of dust and other impurities. In order to test the effect of high humidity, readings have been made at several points along the Pacific Coast for comparison. Further tests of the quality of forest light have been made with a new portable spectro-photometer. All of these have confirmed earlier observations to the effect that forest light is "white light" and contains the various rays in essentially their normal proportion. Unfortunately, no opportunity has yet been found for testing the light quality in such dense forests as those of cedar and hemlock on the Pacific Coast and of beech in the East.

Ecology of Root Systems, by J. E. Weaver.

The root systems of a large number of dominant and subdominant species of important plant communities have been examined with reference to their relation to the nature of the soil, the amount and penetration of the water-content, and to competition with each other. Studies have been made in the climax prairie at Lincoln and the sub-climax prairie at Peru, Nebraska, the short-grass plains and sandhills at Colorado Springs, and in the gravel slide, half-gravel slide, Douglas-fir, and Engelmann-spruce forest at the Alpine Laboratory. In all, 134 species have been studied, the great majority of which are perennial herbs and grasses. These are distributed among the various communities as follows: prairie, 41 species; plains, 30; sandhills, 14; gravel slide, 9; half-gravel slide, 12; forest, 17. In addition, a special study was made of the roots of 12 polydemic species which exhibited ecads in several different habitats. The method employed was to excavate a trench to permit a complete view of the root system in its entire depth and breadth. This sometimes required trenches 25 feet deep and 15 feet long. In the case of *Yucca glauca*, roots were traced in all directions to a distance of over 30 feet from the parent plant. All root systems were drawn to scale or photographed in position whenever this was possible.

The character and location of the root systems were found to be correlated with the water-content in nearly all cases. In the gravel slide and forest, where the maximum water-content is in the first 12 to 18 inches of soil, root systems are uniformly shallow. The plants in the half-gravel slide are somewhat more deeply rooted, probably owing to the greater competition. The sandhills resemble the gravel slide in having a sand mulch of 2 to 3 inches which keeps the soil moist in the upper layer. As a consequence, the roots of sandhill species spread widely in the first foot or two and many of them are relatively shallow. The plains and prairies are much alike in regard to root behavior, the chief difference being that the roots of plains species spread laterally to a much larger degree, while those of the prairie species go more directly downward. Maximum penetration was recorded for the prairie, in which *Kuhnia* and *Lygodesmia* reach depths of 18 to 20 feet, and *Rosa* of 22 feet. The great majority of the roots are highly plastic, as is shown by those of ecads especially, but some species, such as *Kaeria cristata* and *Allionia linearis*, possess very stable root systems. In determining the competitive relations of plant roots in the same community, use has been made of the quadrat-bisect described elsewhere. The detailed study of roots was begun in Washington and Idaho in 1914, and a résumé of these results is also given in the proposed monograph on root systems.

Reciprocal Transplants, by F. E. Clements and H. M. Hall.

A new method has been devised for transplanting related species and ecads to determine the effect of a change of habitat in causing adaptation and variation and in producing new forms. In the earlier work at the Alpine Laboratory species were merely transferred to habitats of measured values and the adaptations correlated with the factors. In the present method the essential feature is the reciprocal planting. This is based upon the presence of paired species or a species and its ecads in neighboring habitats. It is best illustrated in the case of *Geranium* and *Erigeron*. *Geranium caespitosum* and *G. richardsonii* are respectively xerophytic and mesophytic minor species or varieties of the same specific stock. Likewise, *Erigeron glabellus* is the shade form and *E. macranthus* the sun form or variety of the same species. In reciprocal transplanting, the plants of each variety are not merely transferred to the other habitat, but each plant of *Geranium caespitosum*, for example, is placed in the hole left by the removal of a plant of *G. richardsonii*. This insures an exact reversal of conditions and permits a clear-cut demonstration of the extent to which the varieties are reversible as well as plastic. For the sake of detailed correlation, determinations of water-content, light intensity, and air and soil temperatures are made at occasional intervals after the plants are fully established. This is naturally during the following year

when transplants are made in the fall, which is the preferred time. A detailed record is made of the transfers and each plant is labeled in such a manner as to indicate its source as well as its reciprocal. Type specimens have also been preserved for comparison and histological material obtained for studies of leaf and stem adaptation.

Variation and Mutation in Epilobium, by Edith Clements.

This is a continuation of researches carried on in the field and greenhouse from 1902 to 1905 to throw light upon the origin of new forms and the relation between variation and mutation. *Epilobium spicatum* was chosen for this work because of the large number of flower and rosette modifications it exhibits, as well as on account of its adaptability to a wide range of habitats. In the early work an unusual number of apparent flower and rosette mutants was secured. Some of these were grown under measured control to determine their range of variation, and others under uniform conditions to ascertain whether the characters could be accumulated and fixed. The present study is being conducted along similar lines, but is devoted especially to the isolation of pure lines and to the experimental production of mutants. The production of flower mutation by manipulating the flow of food to different parts through pruning, mutilation, change of position, correlation, etc., has proved unusually successful. It is planned to grow these during the year to determine the extent to which such artificial mutants are fixed or are capable of being fixed.

Experimental Pollination, by F. E. Clements and Frances Long.

Considerable progress has been made in extending the experimental studies of flowers and insects begun in 1912. A method of experiment has been devised for the purpose of testing the mutual responses of flowers and insects, many of which have heretofore been accepted upon the basis of mere observation. This method has grown out of several summers' study of the life-history and pollination behavior of the flowers of 70 species. It consists of a number of experimental devices for testing the value of various floral structures and characters, as well as the perception and habits of pollinators. These fall into a number of categories, of which the following are the most important: (1) changes of flower or plant position, or of the time of blooming; (2) transfer of flowers to plants of different floral type and the use of mixed field bouquets; (3) changes in the color of the corolla by painting or masking; (4) changes in the position of petals, sepals, stamens, styles, staminoids, and nectaries, and hence often in the shape of the flower; (5) changes by removal or mutilation of parts, such as cutting a tubular corolla into its original parts; (6) addition of parts or of extraneous substances, such as honey, perfume, etc.;

(7) use of wire cages to confine pollinators to certain plants or species. The results obtained have thrown much light upon the actual functions of flower parts and have furnished a large amount of interesting material on the habits and individuality of insects in particular.

Field and Garden Study of Genera and Species, by F. E. Clements and H. M. Hall.

A general investigation of taxonomic criteria has been under way in the Rocky Mountain region for a number of years, and more definite studies on the *Madieæ* in field and garden have been carried on for a similar period. During the present summer, several important and widely distributed genera have been made the subject of a special inquiry into criteria and their application to the problems of distinguishing species from such minor units as varieties, ecads, mutants, elementary species, etc. The genera selected were *Chrysothamnus*, *Artemisia*, *Atriplex*, and *Haplopappus*. In the latter, a large number of generic segregates have been recognized by recent authors, and hence generic as well as specific criteria are here concerned. The field study of the variants has reached the point where it has proved possible to make a working outline for the species and to relate the various segregates provisionally to them. This constitutes the basis for the application of statistical and experimental methods by which it is hoped to outline a synthetic system based upon evolution and relationship. This should not only permit the grouping of segregates of all sorts about the proper parent species, but should also determine the nature of the minor unit, whether variant, ecad, mutant, etc. At the same time, it is proposed to furnish a convenient and accurate way of designating species and their minor units.

Climax Formations, by F. E. Clements.

In accordance with the general plan for making the knowledge of the vegetation of the West available as rapidly as possible, much attention has been paid to climax formations and their successional development. The major attention has been given to the formations of widest extent, such as grassland, sagebrush, mesquite, and chaparral, but all have been studied to some degree with one or two exceptions. In this connection all the States west of the Missouri River have been traversed by automobile, with the exception of Montana and Nevada. From 1913 to the present time, all of the 16 Western States have been repeatedly crossed and recrossed in the investigation of climaxes and succession. As a consequence, it has been possible to recognize and delimit the various associations of the 9 climaxes for the first time and to point out their relationships to each other, as well as to the associations of adjacent formations. It has also permitted the drawing of more definite distinctions between climax and

successional indicators, and the application of this to practical problems in grazing and forestry. The vegetation studies of the six years have afforded such justification of the developmental treatment of formations and its basic importance for indicator purposes that a fairly extensive account of the climax formations and their associations has been given in the monograph on indicator plants.

Climatic Cycles, by F. E. Clements and A. E. Douglass.

The investigation of climatic cycles has been continued from both the biological and astronomical approach. The former gains interest from the fact that the years 1916, 1917, and 1918 have in general been years of drought in the West and especially the Southwest. This was suggested as a probability upon the approach of the sun-spot maximum in 1916. The maximum was passed in 1917, and attention is now centered upon the expected increase of rainfall generally as the sun-spot minimum is approached during the next four or five years. It is proposed to follow the biological effects as seen in growth, reproduction, and abundance as closely as possible and to correlate these with the climatic phases. Striking evidences of these effects have been obtained during the drought of the past two years. By far the most important problem, however, is the relation of the sun-spot cycle to the climatic and growth cycles. There appears to be little question of the usual coincidence of these three cycles, but the existence of a causal relation is still in doubt. In the endeavor to make use of the sun-spot cycle to anticipate climatic changes, this matter is of paramount importance. For this reason, a re-examination has been made of the pine and *Sequoia* sections upon which the original conclusions were based. New material has also been secured from the *Sequoia* forests during the present summer for the purpose of resolving several doubtful points. In addition, it is hoped to extend the correlation of tree growth and sun-spot cycles into the geological past by the examination of sections of fossil trees from different periods. The biological aspects of climatic cycles are discussed in the monograph on indicator plants. It is proposed to prepare a detailed summary of all the results so far obtained in the study of sun-spot cycles and climatic cycles, and in particular of the evidence obtained from the growth of trees.

Permanent Quadrats, by F. E. Clements, Edith Clements, and G. V. Loftfield.

The progress in the study of climax formations and their successions has made it increasingly evident that the method of observation and comparison is approaching its limit of usefulness (Clements, 1916, p. 423). To reduce the personal equation to the minimum and to eliminate interpretation as much as possible, it is necessary to devise a method by which climate and vegetation furnish their own record

in plant terms to a large degree. This can be done only by means of permanent quadrats and definite vegetational experiments carried through a series of years, preferably the 12 to 15 year period of a sun-spot cycle. As a consequence, an especial endeavor has been made during the year to select locations for permanent quadrats in the various climaxes and their most important seral areas. Some of these have already been installed and charted at such widely separated points as Tucson (Arizona), La Jolla (California), Eugene and Bend (Oregon), Logan (Utah), Colorado Springs, etc. A considerable number have also been installed in connection with cooperative studies on carrying capacity and the effect of eradicating rodents from grazing ranges. It is hoped to increase the number until every climax is adequately represented in its various associations and to make the most important of the quadrat installations regional centers for quantitative studies and vegetation experiments. In the attempt to secure a record of plant parts below ground, a quadrat-bisect method has been devised by which depth, spread, and competition relations may be charted for the wet and dry phases of the cycle.

Indicator Plants, by F. E. Clements.

The special study of indicator plants carried on during the past five years has been completed, and the results have been embodied in a book to be published during the year. It has become more and more evident that indicators are of the greatest importance practically as well as scientifically. Hence, a particular effort has been made to render the results of the widest service to agriculturists, foresters, and grazing experts, as well as to ecologists. For this reason an account has been given of the results of other investigators in so far as they deal directly with indicator values. While it has proved possible to greatly increase the number of indicators and to definitize their meaning and application, it is recognized that precise quantitative values can be assigned to but few at present. In spite of this the general values which can be given mark a decided advance in our knowledge, and permit the outlining of a definite system of indicators which can be filled in as experimental and quantitative investigations increase in number.

Grazing Research, by F. E. Clements, Edith Clements, and G. V. Loftfield.

Grazing problems have constituted one of the major lines of research throughout the year. Because of their emergency nature under war and drought conditions, a vigorous effort has been made to secure effective cooperation throughout the West. This has been remarkably successful, with the result that the Institution is now cooperating informally but effectively with several bureaus of the Department of Agriculture and the majority of the western experiment

stations. Indeed, it has been the chief factor in bringing about a realization of the imperative needs of the grazing industry in the present emergency. In the course of the work, all but 3 of the 15 experiment stations have been visited, while grazing experiments have been started or planned at each of these. Inclosures for the study of carrying capacity under complete protection, as well as in areas where rodents are eradicated, have been established in several States, and it is hoped to install them in practically all. Several months have been devoted to a grazing reconnaissance which has covered 12 States and has permitted a careful comparison of grazing conditions in them.

Rubber Plants, by H. M. Hall and Frances Long.

An extensive survey of the Great Basin region for rubber-producing plants was begun in 1917 as a war-emergency project. During 1918 this has broadened into a comprehensive search throughout the West for all species known or suspected to contain rubber. It is proposed to continue this work as a far-reaching piece of research to determine all the possibilities of rubber production in the West, from native plants at least. A small chemical laboratory was fitted up at the Alpine Laboratory for the grinding and extraction of the plant material during the summer, and later analyses were made at the University of California and the Desert Laboratory. In addition to species of *Chrysothamnus* and *Ericameria* studied previously, 18 genera and 30 species have been examined chemically. These were largely latex plants, though a number were composites related to genera known to contain rubber. In most cases, the leaves and stems were analyzed separately. Rubber was found in 25 of the species examined, but in most it was in too minute a quantity to be of importance. In 11 species, however, the percentage was sufficiently high to justify further investigation, and in 4 of them it was high enough to warrant the hope that the species may serve for the production of rubber on a commercial scale.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2-16.)

The work of the year has followed three closely related lines: (1) a study of cosmic units as such with a view to bringing out, for comparative use, such common properties as are essential to their organization; (2) the development of modes of using these common properties in concrete questions of cosmic evolution in fields where other lines of treatment are not now available; (3) continuation of previous inquiry into certain factors of geologic climate which have come to be entangled with the broader issues of cosmic evolution.

Certain phases of these inquiries had been developed in previous work. For example, in the report of last year, the dynamic properties of spheres of gravitative control were employed in the discussion of certain observed peculiarities in the distribution of nebulae. So, in a similar way, the horizon of the maximum accelerating power of gravity in clusters of stars circulating about an open centroidal region was brought into service as an auxiliary factor in determining the distribution of nebulae. In earlier studies, the sphere of gravitative control of the earth was made the basis of a study of the outward extension and the dynamic state of the outermost atmosphere. During the past year, however, studies in these lines have taken on a much more definite form and have developed into specific inquiries into the organic nature of cosmic units and into the availability of their essential properties in the solution of outstanding questions of a cosmologic order. An outline of these studies has been in preparation for this report of progress, but on account of its length and for other reasons it is reserved for publication separately.

HISTORY.

Andrews, Charles M., Yale University, New Haven, Connecticut. *Preparation of a general history of the colonies in America.* (For previous reports see Year Books Nos. 14-16.)

No additional investigations in manuscript sources have been pursued during the past year, but steady progress has been made in arranging material and in planning the scope and character of individual volumes of the work.

Osgood, Herbert L., Columbia University, New York. *Completion of an institutional history of the American colonies during the period of the French wars.* (For previous reports see Year Books Nos. 11-16.)

At the time of Professor Osgood's death, September 11, 1918, the work in question was nearly complete in four volumes. Since then the Institution has made arrangements with Dr. Dixon R. Fox, a colleague of Professor Osgood in the department of history of Columbia University, to undertake such additional contribution and supervision as may benecessary to complete the project and prepare the manuscript for the press.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature.* (For previous reports see Year Books Nos. 11-16.)

During the last year Dr. Bergen has brought his work on the glossary of the Troy Book to the point reached by the latest parts issued of the Oxford Dictionary and has also continued the work of preparing the manuscript of the glossary for the press. The latter part of the year has been occupied in seeing the proofs of the Fall of Princes through the press and in writing the side-notes for this text.

Tatlock, John S. P., Stanford University, California. *Preparation of a Concordance to Chaucer.* (For previous report see Year Book No. 16.)

During the last part of 1917, Professor Tatlock completed the work of sorting and alphabetizing the 300,000 to 400,000 slips for the Chaucer dictionary or concordance, which were made in England some forty years ago, and had been the basis for the work of the late Professor Flügel. In this task Mr. A. A. Bennett and Dr. Arthur G. Kennedy were capable and generous collaborators; and valuable assistance was received from Professors W. H. Carruth, Raymond M. Alden, and L. E. Bassett. After results had been verified in every possible way, it appeared that about 0.4 per cent of the slips were lacking, with no practicable method of discovering which they are. Previously it had not been possible to test the material for completeness. It now appears to be necessary to have new slips made by a more reliable method. Since there is a prospect that a new text of Chaucer's works may be available in a few months, it has been decided to suspend the work until early in 1919. Meanwhile certain statistics and other information have been gained from the old slips which will facilitate working with the new.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of Cremona Groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9-16.)

Part III of Professor Coble's series of articles on "Point Sets and Cremona Groups" appeared in the Transactions of the American Mathematical Society, Vol. XVIII, July 1917, pp. 331-372. Herein the utility of the general idea was exemplified by a detailed application to the classic problem of the lines on a cubic surface. The methods indicated are quite different from those given by Klein and Burkhardt, though ultimately of course the same functions and groups appear. The next application in order would be to the double tangents of a plane quartic. This is not so immediate, because the various allied problems have not yet been developed in good form. Thus no collineation group isomorphic with the group of double tangents has been discussed. This lack will be supplied to some extent in the forthcoming dissertation of C. C. Bramble.

The hypothesis of a connection between the self-associated point set P_{2p+2}^p and the theta-modular functions of genus p has been verified. It appears that the infinite discontinuous collineation group g_n, k of point sets II has invariant subgroups whose factor groups are isomorphic with known theta-modular groups. The nature of these

groups has been established in the article Theta Modular Groups Determined by Point Sets (Amer. Jour. Math., vol. XL, Oct. 1918).

The abstract verification of the connection mentioned unfortunately affords no clue to the algebraic nature of the connections. To clear this up the geometric properties of the P^4_{10} are under investigation, in the hope that with the P^2_6 disposed of, and the P^3_8 in manageable form, the geometry will throw light on the required relations. It may well be that when these three cases are completely developed, the general nature of the relations will be apparent.

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics in practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-16.)

Dr. H. U. Sverdrup, who during a period of more than eight years has served successfully as scientific assistant of the Carnegie Institution of Washington, retired at the beginning of this year in order to devote himself entirely to the scientific equipment of Amundsen's North Pole expedition, and has departed as scientific leader of that expedition. In the service of the Institution he has been succeeded by Mr. J. Bjerknes.

It was pointed out in the previous report that a principal reason why every calculation of future wind has been a failure is the complicated nature of atmospheric friction in the neighborhood of the ground. The investigation of this friction has therefore been continued. Choosing suitable data of observations, we have succeeded in finding further characteristic features of it. The investigations have been conducted to a point where new experimental or observational data are desirable. Such observations have been planned, but no opportunity for practical use has been presented.

The law for the propagation of lines of convergence and divergence announced in the previous report* has been the subject of further research. The testing of these laws made it necessary to draw very detailed synoptic maps. These detailed maps have made evident that every cyclone which is not perfectly stationary has two characteristic lines of convergence, which are intimately related to its propagation. Reckoned relatively to the tangent of the track, both lines come in from the right side (on the southern hemisphere from the left side), but under different angles. One forms approximately a right angle with the track. The other clings more closely to the track and seems to touch it at the cyclonic center. Drawing the tangent to this line of convergence at the center of the cyclone, we therefore

*See the more complete account of J. Bjerknes listed in the Bibliography, p. 31.

find the momentary direction of propagation of the cyclone. On account of this property this line of convergence may be termed the *steering-line*. Simultaneously the velocity of the propagation may be computed approximately by the differential properties of any one of the two lines of convergence.

The importance of these lines is increased by their meteorological properties. The warm air providing the cyclone with a part or with all its energy flows in the sector bordered by these two lines. During the propagation of the entire system the steering-line will form the front of a propagating warm wave. In the same manner the other line will form the front of a propagating cold wave. This cold wave is much more marked than the warm one, and is followed by heavy rain, falling from the warm air which is lifted by the propagating cold air. In many cases this rain is associated with thunder and violent wind. This line of convergence is therefore in reality identical with the *squall-line*, which has often been observed to accompany cyclones. The steering-line is not accompanied by so violent meteorological phenomena as the squall-line, though when sufficiently near the cyclone it gives much rain. This rain, which does not merely follow after the line, but may precede it up to 200 kilometers or more, falls from the warm air sliding up the slightly inclined plane which separates the upper warm air from the underlying cold air, which is swept away during the propagation of the cyclonic system.

The investigation of these two characteristic lines of convergence will evidently be important not only for the theory of cyclones but even for practical weather forecasting. The success of the practical methods will, however, depend upon the completeness and exactitude of the meteorological observations. Great attention must be paid to the observation of the wind, especially its direction, and the stations for observing the wind must be much more numerous than meteorological stations of the first class now employing telegraphy.

In order to utilize the new methods for the Norwegian weather service during the most important summer months, a great number of stations (observing only wind and weather) have been interpolated between the first-class stations. The result has been encouraging. This system has made it possible to give satisfactory weather forecasts in spite of the enormous difficulty arising from the lack of weather telegrams from the surrounding countries involved in war.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-16.)

Many questions calling upon the science of nutrition for an answer have been raised as a consequence of the world war involving the health and maintenance of great groups of people. Fortunately the outcome of the investigations conducted for several years, under previous grants to us, made it logical to apply the results already obtained to a solution of many of these questions. For some time, therefore, we had been relating the findings of our purely scientific researches more and more to solutions of some of the problems of nutrition met with in daily life. Since this country entered the war we have naturally been impelled to give this trend of our researches fuller play, so that they might contribute as far as possible to a helpful solution of some of the impending problems.

In doing this we are further encouraged by the faith that after the war what we are now learning of the essentials of nutrition may be perhaps even more useful than during its progress. The enormous number of people who are already suffering from malnutrition is likely to increase steadily until the world will be threatened with the diseases which invariably follow in the wake of famine. More widespread recognition of the fact that specific dietary deficiencies are often the factors which lead to the development of some of these diseases can hardly prove otherwise than helpful in dealing with them successfully.

Physicians, especially in regions affected by the war, are reporting cases of unusual eye disease among children who had been fed largely on skimmed milk or otherwise restricted diets. This affection of the eyes appears to be similar to the condition recognized in rats by Knapp in 1908, but which in 1913 we first associated with diets deficient in the fat-soluble vitamine. By substituting whole milk for skimmed milk or by administering cod-liver oil these children are reported to be cured as readily as our rats are cured by adding the fat-soluble vitamine to their diet. Observations on animals living upon diets deficient in fat-soluble vitamine have thus strengthened the evidence of important interrelations between diet and disease.

It is gratifying to find in current physiological literature the widespread acceptance of various facts relating to the relative nutritive value of the proteins, the role of the various amino-acids and their relation to the protein minimum, the part played by the vitamine properties of food substances and their relation to disease conditions, the highly specific antigenic properties of isolated proteins, etc., which we have dwelt upon in previous reports. Many of our findings and

the experimental methods which we have developed are proving useful to other investigators in connection with their studies in related fields.

In view of the extraordinary effects observed in our earlier experiments, when vitamins were removed from or added to otherwise adequate diets, we have been largely occupied during the current year with experiments to determine the distribution and relative proportion of these essential factors in various animal and vegetable foods. This seemed important, as information in this field has been very scanty and practically none of it has been of a quantitative character.

We have undertaken to determine the minimal amounts of the following animal tissues which furnish sufficient water-soluble vitamin for the growth of rats: skeletal muscle, heart muscle, liver, kidney, brain, and pancreas. Thus far we have learned that skeletal muscle (round of beef) furnishes so little of this vitamin that meat must be counted on as a minor source of this food factor in the human dietary. On the other hand, the heart muscle is richer in water-soluble vitamin and appears to contain not a little of the fat-soluble. Liver and kidney likewise contain both of these vitamins in comparatively considerable quantities, while brain tissue contains less of the water-soluble vitamin than any of the above animal tissues except skeletal muscle. As to the fat-soluble vitamin in brain or either vitamin in the pancreas, we are not yet prepared to make definite statements. Incidentally we have established that each of these animal tissues, except the pancreas, contains protein adequate for normal growth. Experiments with pancreas are not yet complete.

Of animal products, milk has been studied in respect to the relative quantity actually required to furnish enough water-soluble vitamin for growth, and also the effect of heating and other treatments on this vitamin. Comparison was made between fresh untreated milk, pasteurized milk, our so-called "protein-free milk," and a commercial milk powder. Equivalent amounts of each of these were equally effective in promoting normal growth, hence the water-soluble vitamin is apparently not damaged by the processes employed in making our protein-free milk, the commercial milk powder, or in pasteurizing milk.

In our experiments much larger quantities of milk were required to furnish enough vitamin for normal growth than is generally supposed to be sufficient. Thus when 12 per cent of milk powder or equivalent amounts of fresh milk or "protein-free milk" were fed, young animals grew little, if at all, although the diet was in other respects wholly adequate. When this quantity was doubled growth was approximately normal. Even the daily separate feeding of 16 c. c. of fresh milk, the solids of which were equivalent to about 25 to 30 per cent of the average amount of food eaten, rarely caused satisfactory growth, and even in the most successful experiments better growth was made when a little yeast was also given. Compared with dried brewer's yeast, or wheat embryo, of either of which 1.4 grams per week fur-

nishes enough water-soluble vitamine for normal growth of rats, the 14 grams of milk solids which are needed to promote similar growth is obviously a relatively large amount.

These results confirm Hopkins's statements respecting the effect on the growth of young rats of the addition of milk to artificial diets; but the amount which we were compelled to add to obtain normal growth was, for some unknown reason, considerably larger than he stated to be needed. According to our experiments, only when milk solids constitute at least 25 to 30 per cent of the total solids of the diet can these be depended upon to furnish enough of this indispensable food accessory to promote approximately normal growth when no other source of this vitamine is present. Knowledge gained by these experiments has been utilized in connection with the shipment of dried milk abroad, and also its use in feeding children in New York City.

Hens' eggs have also been studied as a source of water-soluble vitamine, and to our surprise we have found that when they are the sole source of this vitamine the diet must contain at least 20 per cent of commercially dried egg solids if normal growth is to be maintained. Animals which inherit the capacity for very rapid early growth, and consequently eat abnormally large amounts of food, can grow on diets containing smaller percentages, but in such cases the absolute amount of vitamine consumed is correspondingly large. Since the egg powder used for these experiments was dried by the same process as was used in making the milk powder above referred to, we have no reason to suppose that the vitamine was thereby damaged. It remains to be ascertained, however, whether or not this is the case.

An extensive series of experiments is in progress with the green parts of plants which are used as food by both men and farm animals, and these have already yielded unexpected results of much interest. These investigations are hardly more than begun, so we are not prepared to report on them in detail. They promise to yield information much needed by dietitians. Work has already been begun on the vitamine content of tubers and it is expected to enlarge the scope of these experiments as supplies become more available. Attention is also being given to the distribution of vitamins in different parts of seeds, and already much has been done in this field in connection with a substantially completed study of the nutritive value of the wheat kernel.

Positive knowledge respecting the nutritive value of the three parts of the wheat kernel into which it is separated by the modern miller has become of special importance, owing to the present scarcity of this grain and the necessity of using available supplies most economically. We have, therefore, thought it desirable to study the relative nutritive value of each of the three parts of the wheat kernel; and results have been obtained which should be helpful in deciding to what extent these

parts should be separated in milling flour in order to use the entire grain most profitably.

This work has demonstrated that the proteins of the entire kernel are adequate for promoting normal growth, provided the animal can be induced to eat enough of them. The endosperm proteins, on the contrary, are much less efficient when compared on their nitrogen basis. The proteins of the embryo and of the bran (provided the animal is able to digest the latter) are much more efficient in promoting growth than are those of the entire kernel. For the maintenance of mature animals somewhat more of the endosperm proteins than of those of the whole wheat or the embryo is required, though these differences do not appear to be so great in the case of maintenance as where growth is involved.

When the wheat proteins are supplemented with proteins from meat, milk, or eggs, less *total* protein is required for maintenance or for normal growth than when the wheat kernel forms the sole source of protein. Since the proteins of meat, milk, or eggs supplement the proteins of patent flour, the latter is mostly used in this country under conditions which permit an economical utilization of its protein. Although the proteins of the embryo and bran also supplement those of the endosperm, the entire kernel does not contain enough protein in these parts to render the endosperm proteins as efficient in promoting growth as when they are supplemented with the animal proteins together with which they are commonly eaten. Hence, from the protein standpoint nothing is to be gained by grinding the entire kernel, except where patent flour forms an excessive proportion of the diet; and in these cases the protein deficiencies of the flour are more effectively met by including a moderate quantity of animal protein in the diet.

Since most farm animals can easily digest the nutrients in bran and embryo, and since the proteins of these parts of the wheat kernel doubtless supplement those of the vegetable foods to which the wheat by-products are almost always added in agricultural practice, it seems certain that the methods of using wheat which prevailed before the war are economical. Although food fed to farm animals is returned in much smaller quantity in the form of human food, it must be remembered that the meat, milk, and eggs thus produced render the protein in the 70 per cent of wheat that goes into patent flour of practically the same nutritive value as that furnished by the more expensive animal proteins, and of far more value than if eaten in the form of either entire wheat or graham flour without a suitable protein supplement.

50 to 60 per cent of patent flour in an otherwise adequate diet furnishes barely sufficient vitamine to promote satisfactory growth, and 30 to 40 per cent is required for maintenance. On the other hand, 15 to 20 per cent of the entire kernel, or as little as 2 to 5 per

cent of the preparation of commercial wheat embryo employed by us, were enough for either growth or maintenance.

So long as the diet of man is sufficiently varied to include enough vitamine from sources other than the cereals, the milling question need not awaken much concern from the vitamine standpoint; but when the diet is restricted the danger of a shortage of vitamine may become real if a large proportion of sugar, fat, or other products, low in their content of water-soluble vitamine, are included in the ration.

Work done under this grant was originally concerned with the chemistry of the vegetable proteins, the ultimate object of which was to acquire knowledge to guide us in the use of our various vegetable food products as well as to shed light on the part played by proteins in nutrition. In the report for 1917 we pointed out how our investigations had now reached the point where definite information should next be obtained respecting the nutritive value of the total proteins of the more important vegetable foods. It was then stated that such investigations had been begun. This work has been continued and a preliminary paper published.* Many technical difficulties have been encountered in learning to make suitable preparations from starch-containing seeds, but as these have been overcome we have now a series of experiments in progress which it is hoped will show the relative nutritive value of the total proteins of the more important cereal grains.

In discussions of the nutritive value of the cereals these are commonly considered as representing the intact seed. In commerce, however, the milling and other factory processes lead to partial disintegrations whereby are obtained diverse by-products frequently representing distinct morphological portions of the seed. As we have hitherto pointed out, such mill-products must no longer be assumed to have a nutritive value strictly proportional to their analyzed content of the proximate principles. The corn germ is one of these. Owing to the recent extensive milling of corn for human consumption, large quantities of corn germs are now on the market. Any information which can be obtained which will make it possible to use this valuable feeding stuff to the best advantage is therefore of importance.

We have found that the corn germ contains proteins which are superior in promoting growth to those found in the endosperm, but inferior to those in the wheat embryo. When supplemented with a small amount of meat or egg proteins corn germ is capable of inducing very rapid growth. It is also rich in the water-soluble vitamine.

At the present time, when legumes are being advocated as "meat substitutes," it is desirable that as much as possible should be known of their nutritive value. We have accordingly begun a study of these important foods and have already confirmed our earlier limited experi-

*Nutritive factors in plant tissues: I. The protein factor in the seeds of cereals. *Jour. Biol. Chem.*, xxxiv, 521, 1918.

ence with some of them and their failure to promote the growth of young rats. Much further work will be required before satisfactory answers can be obtained to the puzzling questions which these experiments have raised.

The study of the chemistry of the milk proteins has been continued; for, strange as it may seem, our knowledge of this subject has been limited.

The coagulum obtained by precipitating casein from milk with acid and heating the filtered serum has previously been shown to contain two proteins, but concerning these the literature contains little that is definite. We have separated these proteins from each other so completely that the preparations did not react anaphylactically with one another, and have determined their ultimate composition and some of their properties. The individuality of these two proteins was demonstrated by anaphylaxis experiments made by Professor H. G. Wells. The phosphatides present in milk are associated with the lactoglobulin, not with the pure lactalbumin. In its relation to the phosphatides, lactoglobulin resembles the vitellin obtained from hens' eggs and has little in common with most other globulins.

The proteose, previously referred to in our earlier report, has now been shown to originate largely from the other proteins of milk. Whether any protein of this class is an actual constituent of fresh milk has not been finally determined and can not be until better methods are available for completely separating all of the other proteins. Our experiments show, however, that the amount of proteose present in fresh milk is, at the most, very small.

We have already reported that we had isolated from the alcoholic washings of large quantities of casein a considerable amount of a hitherto unknown protein which, like gliadin from the wheat kernel, is freely soluble in 50 to 80 per cent alcohol, but insoluble in absolute alcohol and largely so in water containing more or less inorganic salts. We have since studied this protein more fully. Toward solvents it behaves quite unlike any protein of animal origin hitherto described. It is distinct from all of the other proteins of milk, as shown by the anaphylaxis reaction and the proportion of some of the amino-acids which it yields on hydrolysis. That this protein is an original constituent of milk and not a product of the action of alkali, or other reagents used in purifying casein, is made almost certain by the fact that it is precipitated together with casein simply by adding very dilute hydrochloric acid to fresh milk. Owing to the fact that its acid compounds are soluble in water, some also remains in the milk serum even after casein has been precipitated by acid and the coagulable proteins by heat.

Our report for 1917 mentioned the beginning of a somewhat elaborate investigation of the rôle of the various inorganic elements in the diet. This line of work has been continued with results which have

in many ways surprised us, for it has been found that animals are able to retain some of the inorganic elements so tenaciously that the effect of excluding these from the diet can be learned only by using ingredients of the food, all of which are free from even traces of the element under observation. Although we prepared the materials for our diets with great care, examination of the ash of large quantities showed the presence of minute amounts of all of the inorganic elements which we were studying. Some of these were unavoidably introduced by the vitamine-containing product which it was necessary to add to the food and which of course could not be treated chemically. The method has consisted in observing the comparative growth of animals on rations in which differences in the quantities of the inorganic elements represented practically the sole variations between the different food mixtures; the effect of removing from the diet all but very small quantities of a given element was thus measured. A lowering of the intake of calcium and phosphoric acid promptly led to an interruption of growth and to nutritive decline if the supply of these elements was too greatly curtailed. We may emphasize anew that any shortage of these elements can be supplied by additions of inorganic salts quite as well as by natural foods containing them; hence calcium, phosphorus, and iron, for example, in natural foods have not the unique value that is commonly ascribed to them. For feeding farm animals, where the lack of calcium in their grain rations is always encountered, complete nutrition can be attained upon diets supplying this inorganic element in the form of its commercial salts.

While relatively large quantities of calcium and phosphoric acid were found to be required for normal nutrition, surprisingly small quantities of chlorine, sodium, potassium, and magnesium, as contrasted with the customary intake of them, were adequate for growth. Rats gained well even when their diet contained less than 0.04 per cent of either sodium or chlorine, only 0.03 per cent of potassium, or only slightly more than 0.01 per cent of magnesium. When the quantities of sodium, chlorine, and magnesium in the food were simultaneously decreased to these low levels, rats still grew at a normal rate. When, however, both sodium and potassium were limited to these small amounts growth ceased. Calcium, phosphorus, and sodium or potassium, all of which are supposed to play an important part in the maintenance of neutrality, are needed daily in considerable quantities, the requirement for the other inorganic elements being very small. Perhaps this explains why either sodium or potassium must be present in fairly large proportion, while either alone can be reduced to insignificant quantities without seriously impairing growth.

To learn to what extent the instinct and appetite of rats are capable of guiding them to a proper choice between foods of unlike nutritive value, a number of animals were allowed to choose freely between two

foods, one of which was more suitable for inducing growth than the other. Although the rats usually ate some of each food offered them, only one failed to select enough of the better food to induce good growth; and it is possible that if the experiment had been continued a little longer this one animal would eventually have learned to make a wiser choice in his diet.

Small, yet measurable, quantities of nitrogenous products are added to our "synthetic" diets when protein-free milk, yeast, corn germ, or wheat embryo are used to furnish the vitamine. In studying the nutritive value of isolated proteins, as well as that of proteins as they occur in animal or vegetable products, this small amount of protein, added with the indispensable vitamine, to a certain extent limits the conclusions that can be drawn from such experiments; for it is never absolutely certain that the good effect produced by the vitamine may not be in part at least due to a favorable supplementing effect by the protein in the vitamine-containing product. Accordingly we have attempted to obtain a vitamine preparation freer from protein than dried yeast, or wheat embryo, which we have usually used in the past as sources of vitamine. This work is in progress, but we have not yet succeeded in securing the desired product.

In our report for 1917 we referred to the good growth of rats when only 1.5 to 2 per cent of yeast supplied all of the water-soluble vitamine of the diet. Twenty-five of these animals ultimately reached a very large size, but all failed to breed when mated with rats raised on the yeast diets, and only four proved fertile with rats raised on the ordinary "mixed food" fed to our stock colony. Even changing the rats from the yeast-vitamine diet to this stock diet failed to render them fertile. Professor H. H. Donaldson kindly examined the reproductive organs of these animals and reported that in the testes of the four animals which he had then examined he found no spermatozoa, no tubular tissue, and an excess of interstitial tissue. His report on the females has not yet been received. This surprising result opens up a wide field for the investigation of the relationship between the vitamine content of the diet and the fertility of the animal.

In our early feeding experiments several rats grew well on mixtures of isolated foodstuffs which were supposedly vitamine-free. Our more recent knowledge of the need of vitamins in the diet supports the conviction that these rats received vitamine from some unknown source. It has been suggested by other investigators that the commercial lactose in their diets contains not inconsiderable quantities of vitamine. We have accordingly undertaken a study of this question, for its answer may give a clue to the nature of the water-soluble vitamine.

As long ago as 1913 we found that, in contrast with various other fats, butter fat contains something absolutely essential for the con-

tinued growth and well-being of young animals. This discovery was also made, independently and simultaneously, by McCollum and Davis, but it has not yet been learned whether this food factor, now known as the fat-soluble vitamine, is also necessary for the maintenance of mature animals. At the present time it is desirable to have a positive answer to this question, for where milk supplies are restricted it is important to know whether adults can safely substitute other fats for butter. Experiments directed to this end are in progress, but do not yet permit final conclusions.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and paleogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8-16.)

The manuscript of the first part of the work upon the paleogeography of North America in the late Paleozoic has been completed and submitted to the Carnegie Institution of Washington. This work includes, as a preliminary chapter, a discussion of the elements of a paleogeographic problem. Then follow chapters upon the stratigraphy, paleobotany, climatology, and physiography of North America in the late Paleozoic. A chapter discusses the interpretation of the deposits and other evidence as revealing the environment of vertebrate life. The final chapter is devoted to a discussion of the development and fate of the vertebrate life in relation to its environment. Evidence is given that the gradual uplift of the continent from the east toward the west produced a great migrating climatic change advancing toward the west and involving successively higher geological formations. This climatic change is traced by the peculiarities of the deposits shown to cut obliquely across the stratigraphic series. The conditions produced by the climatic migration are designated as "Permo-Carboniferous conditions" and are recognized as a distinct geological unit independent of any distinct period of time. The correlation of these conditions largely removes the difficulties in understanding the distribution, geographic and stratigraphic, of the late Paleozoic vertebrates.

It is also shown that the elevation of the western side of the continent of North America in late Paleozoic time terminated the migration of the great climatic change and converted the northern portion of the Basin Province into a region of stagnant seas, in which were deposited the sediments of the Park City formation of northeastern Utah and the equivalent formations of adjacent States.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia.
Associate in Paleontology. (For previous reports see Year Books Nos. 11-16.)

Since the last report was rendered Dr. Hay has been working mostly on the Pleistocene geology and vertebrate paleontology of the Atlantic coast plain from southern Florida to Massachusetts. Some of the conclusions thus far reached on Pleistocene geology and on the history of its vertebrated animals he states as follows:

1. At an early time in the Pleistocene period the vertebrate life of our continent was extremely rich. That of the present time is relatively greatly impoverished.

2. It is impossible to say to what extent new species have been developed since the beginning of the Pleistocene. It would be unsafe to say that any particular existing species did not live during the first interglacial stage.

3. The species and genera of vertebrates suffered extinction during the Pleistocene to a surprising extent. Of a list of over 600 reported species, nearly 60 per cent are extinct. Among these are several genera of ground-sloths, two genera of mastodons, three or four species of elephants, as many of camels, two species of tapirs, many species of horses, many of bison, several species of peccaries, and various tiger-like cats and saber-tooth cats.

4. The five glacial stages and the stages of mild climate that succeeded each of them furnish us a means for determining, in at least a general way, the times when many important species became extinct. The camels, nearly all of the species of horses, species of *Hipparion*, *Elephas imperator*, the species of mastodons belonging to *Gomphotherium*, the edentates belonging to *Megatherium*, *Glyptodon*, and *Nothrotherium*, appear to have died out before or during the Kansan glacial stage. The tapirs, the few remaining horses, the long-horned bison, the saber-tooth cats, and *Myiodon* probably disappeared before the oncoming of the Wisconsin ice-stage. Two species of elephants, the common mastodon, species of peccaries, the giant beaver, *Megalonix*, and the moose *Cervalces* persisted through the vicissitudes of several stages and then succumbed when conditions appeared to be wholly favorable for their existence.

5. The low-lying formations known as Cape May in New Jersey, most, perhaps, of the Talbot of Maryland, and the Pamlico of North Carolina appear to have the age of the Wisconsin. Their few known vertebrate fossils favor this assignment. The older formations, known in New Jersey as Bridgeton and Pensauken, in Maryland as Sunderland and Wicomico, in North Carolina as Coharie, Sunderland, Wicomico, and Chowan, appear to have approximately the age of the first interglacial, the Aftonian. An Aftonian fauna is present at Vero, Florida, and at Charleston, South Carolina. By the presence of horses

the early Pleistocene may be followed northward through North Carolina, along the Potomac to Washington, to Chesapeake Beach on the west shore of Chesapeake Bay, to Swedesboro, Fish House, Navesink Hills, New Jersey, to Throg's Neck, New York, and possibly Martha's Vineyard, Massachusetts. At Fish House, horse remains are definitely located in Pensauken (approximately Aftonian) clays. At Port Kennedy, Pennsylvania, 22 miles away, in a cave, over 50 species of mammals have been found, of which 80 per cent are extinct.

6. The Lissie and Beaumont formations of Texas belong likewise approximately to the time of the first interglacial stage, inasmuch as they contain remains of camels, horses, megatherium, and *Elephas imperator*.

7. The great body of the Sunderland and Wicomico formations and their equivalents of whatever name, also the greater part of the Talbot and of the Chowan, were not laid down in the sea, but above sea-level along the lower reaches of rivers. The Sunderland and Wicomico are destitute of marine fossils; the Talbot and Chowan afford such fossils only along the existing coast and estuaries. All of these formations do contain land animals, elephants, mastodons, and (except the Talbot and its equivalents, Cape May and Pamlico) horses. The same statements are true regarding the Lissie and the Beaumont of Texas.

8. At Vero, Florida, associated with the early Pleistocene fauna, have been found bones and other relics of human beings. These appear to have the same geologic age as the fossil mammals. In a deposit at Charleston, South Carolina, intimately associated with mastodon and horse, a piece of pottery has been found.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in Paleontology*. (For previous reports see Year Books Nos. 2-4, 6-9, 11-16.)

Comparative studies of Rhätic floras, sectioning of South American coniferous woods, preparation of a volume on Anatomy, in continuation of American Fossil Cycads, Vols. I and II, a closer examination of the fossil evidence bearing on the origin of dicotyls, and some attention to related topics, lists the main activities of the present year. Incidentally it has been necessary to study the subjects of *extinction* and *parallelism*. Notes touching on these subjects have been given or are in preparation. Especially the anatomical facts of the fossil record bearing on homoplastic origins carry us hard by the field occupied by Clements's* "Plant Succession." Another highly important boundary-line to which the study of the Cycadeoids has been extended, is that of dicotyl stem structure. There is already in evidence among botanists a vigorous conflict of opinion as to what

* Clements, F. E.: Plant Succession. An analysis of the development of vegetation. Carnegie Inst. Wash. Pub. No. 242, 527 pp. (1916).

are the older and the newer dicotyl-stem types; and such a fact best attests the validity of the claim that the study of the cycadeoids has brought into a more normal perspective certain larger factors of dicotyl (as well as gymnosperm) stem evolution.

Some attention has been given to the limits of fossil evidence, or the negative phases of antecedent relationships of fossil forms to present groups. It appears that a more persistent scanning of the negative or inferable side of the fossil record will prove helpful in gaining a better appreciation of the main course of change. Views have been too nearly restricted to the bare chronologic record. Thus it has been supposed that there was a general absence in the Jurassic and earlier floras, of the higher types of seeds, flowers, foliage, and stems. This view is inadequate. As a later development of the study of the Cycadeoids there has been found within the greater series a striking lesser group of blade-leaved, small-stemmed, small-flowered plants, the Microfloræ, now known to have had a world-wide distribution in the Mesozoic. The discovery of this group profoundly affects our views of the probable character of early dicotyl foliage and of fructification.

The small-flowered Cycadeoids, or Microfloræ, show that the early angiospermous flowers may in like degree have failed to leave a record; and they also invite attention to the theory of polar and upland early angiosperm stocks. The stems of the Microfloræ are rarer still than the flowers. A single petrified stem of one of these plants from the early Trias would doubtless reveal structures leading toward the early dicotyl-stem types; yet after nearly twenty years of search in museums and afield not a fragment with structure conserved has been found. Nevertheless the Cretaceous conifer stems from Kreischer-ville, on Long Island, so satisfactorily investigated by Hollick and Jeffrey some years since, show how stems of the Microfloræ must occur and sooner or later be discovered. That these stems had features similar to those of the better-known Cycadeoids is certain enough; but they varied far more, as indicated by form, foliage, and habitat.

Similarly, when we turn to the leaf record. Within the Microfloræ, despite their unknown stem structure, the Triassic approximations nearest to dicotyledonous plants are discovered. Taking into consideration the general leaf types in evidence from the Rhätic to the Lower Cretaceous, it is thus of great interest to find how simple could have been a course of change from the parallel venation of the ancient bladed-leaf types seen in the Microfloræ into the magnoliaceous type of venation. By the drawing apart of the lateral parallel veins in *Stangerites*-like leaves with relative increase in vein-size and a correspondent invasion of the *marginal net*, the typical dicotyledonous blade would be reached. Vein bulk would thus remain the

same; but the leaf would acquire a more plastic character, fitted to more varied environments, as in the Cretaceous *Liriodendropsis*. Lobing, clefting, and dividing could readily follow, and, with development of opposite basal veins, trifold types and also palmate forms.

Moreover, there is no evidence of fusion of cycadeous pinnules; the spinose cycadeous types like *Dioon* and *Encephalartos* are in accord with their position in time, terminal, or extreme forms. A great extent of ginkgoid foliage in the Rhätic and variety in cycadeoid foliage in the Jura are two great developments preceding the appearance of palmate forms in the Potomac. But palmate leaves need not be regarded as more distinctly primitive than bladed forms; and double as opposed to single leaf-traces must be regarded as having been anciently separated and distinct from the Paleozoic on. From these cognate facts it appears that with the discovery of but few additional forms the actual record of pre-Cretaceous dicotyl leaf and stem development may be brought into view.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7-16.)

Professor Carl Barus has recently submitted a report* of an investigation of methods of research by which displacement interferometry with the aid of the achromatics discussed in the preceding report,* gives promise of fruitful applications. In Chapter I the method of measuring small angles hitherto suggested is given a practical test; the general theory of the subject in its bearing on the two possible methods is developed at some length, and a variety of interferometer devices, with mirror, ocular, and collimator micrometers, are instanced. In connection with these experiments a method of reducing the fringes to the smallest number possible, practically to a single fringe, is elucidated.

As the achromatic fringes can not (in general) be found without first finding the corresponding spectrum fringes; and conversely, since for each type of spectrum fringes (direct or reversed), a corresponding group of achromatic fringes may be associated, Chapter II treats of spectrum fringes differing in their manner of production. The endeavor has been to obtain interferences from distant slender luminous objects, without the aid of a slit. Partially, at least, the work has succeeded.

The work in the third chapter was undertaken at the request of Professor W. G. Cady, of Wesleyan University, in an endeavor to

* Carnegie Inst. Wash. Pub. No. 249, part II, chapters V, VI (1917).

obtain the elastic constants of small bodies. The application of the displacement method proved at once to be astonishingly easy in a case where a degree of rough handling is inevitable.

Chapter IV contains applications of the rectangular interferometer, using achromatic fringes, to geophysical problems. A method for the determination of the Newtonian constant is worked out. Again, the same interferometer is associated with the horizontal pendulum for the detection of small changes in the inclination of the earth's surface. A series of observations extending between January and August are recorded.

The last chapter is devoted to corresponding methods for the interferometry of vibrating systems. The luminosity of the achromatic fringes lends itself easily to this purpose, and it was merely necessary to design an appropriate vibrating telescope. To test the method a study is made of the vibration of telephonic apparatus. Clear-cut interference vibration curves are shown for two identical telephonic systems joined directly in series, while these forms subside completely when the telephones are joined differentially. Such a system is also an electric dynamometer capable of appreciating an average alternating current well within a microampere. It could, moreover, be synchronized relative to an external electric impulse by aid of the Lissajous curves, with the same accuracy as two tuning-forks.

Howe, Henry M., National Research Council, Washington, D. C. *Research Associate in Metallurgy.* (For previous reports see Year Books Nos. 6-16.)

Most of the year 1917-18 has been devoted, under the joint direction of the National Research Council and the Ordnance Department of the War Department, to seeking material with great ballistic resistance when in the form of the very thin sheets used for helmets and body armor. The general policy of these bodies forbids my giving any indications of the results reached. An interesting phenomenon is the spontaneous development of large volute aging cracks, sometimes with a loud report, weeks and even months after ballistic testing.

I have proved that agitation during solidification, for instance by rotation at a continuously varying rate, prevents in metals the formation of the coarse columnar crystals of the class which in steel ingots do so much harm by concentrating at their boundaries certain of the impurities contained in the molten metal, and thus creating regions of great enrichment in those impurities and consequent brittleness of the mass taken as a whole.

I have done much work in systematic attempts to correlate the microstructure, thermal treatment, and mechanical properties of steel, and to throw light on the mechanism of plastic deformation.

Nichols, E. L., Cornell University, Ithaca, New York. *Systematic studies of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4-16.)

THE LUMINESCENCE OF CALCITE.

The discovery that certain uranyl salts excited by kathode rays at a temperature of -180° exhibit phosphorescence of long duration, although the same substances under photo-excitation glow for a few thousandths of a second only,* has been extended to the calcite of the Franklin Furnace region.† We have studied the ruddy luminescence of this calcite in detail and have established the following facts:‡

(1) Under photo-excitation the phosphorescence vanishes in about 0.3 second.

(2) The curve of decay corresponds with that previously found in the case of the photo-luminescence of the uranyl salts and hitherto supposed to be characteristic of and confined to those substances.§

(3) The color, intensity, and duration of the luminescence are not strikingly modified through a considerable range of temperature, but the color appears to be of a purer red at -180° than at $+20^{\circ}$ and tends toward yellow at still higher temperatures. This observation was verified for the higher temperatures by measurements of the relative brightness of two regions of the phosphorescence spectrum (0.65μ and 0.52μ) at temperatures between $+20^{\circ}$ and $+300^{\circ}$.

(4) At about $+350^{\circ}$ the activity of this calcite, like that of the calcites from Joplin, Missouri, and Fort Collins, Colorado, long since described by Headden,¶ ceases entirely and becomes non-luminescent.

(5) The calcites studied by Headden are strongly thermo-luminescent between about 60° and $+200^{\circ}$, a statement which we have had the pleasure of verifying from specimens kindly furnished by that observer. The Franklin Furnace calcite, on the other hand, displays no thermo-luminescence whatever under the above conditions.

(6) The luminescence is unquenched by red or infra-red radiation applied during or subsequent to excitation.

(7) The Franklin Furnace calcite contains appreciable amounts of manganese and it appears that the characteristic ruddy luminescence of this mineral depends upon this admixture. One writer (Wilber) showed that a similar luminescence could be produced in pure calcite by the addition of a manganese salt and suitable heat treatment.

(8) Although the luminescence spectrum appears to the eye to consist of a single broad band extending from red to blue, detailed spectro-photometric measurements indicate a complex structure. The spectrum consists of at least two systems of components having

* Wick and McDowell; Physical Review (2), xi, p. 421 (1918).

† Nichols, Howes, and Wilber: Proc. Nat. Acad. Sci. (1918).

‡ Nichols, Howes, and Wilber: Physical Review (2), xii, 351 (1918).

§ Nichols and Howes: Physical Review (2), x, 293 (1917).

¶ Headden: Amer. Jour. Sci., (4), xxi, 301 (1906).

constant frequency intervals. Neighboring bands overlap to such an extent that they can not be visually distinguished, even at the temperature of liquid air.

(9) Under kathodo-excitation this calcite shows brilliant phosphorescence of long duration (measurable for 300 to 400 seconds). The form of the curve of decay is that characteristic of all substances of persistent phosphorescence thus far determined.

(10) This persistent phosphorescence, unlike the kathodo-phosphorescence of the uranyl salts already referred to, occurs not only at -180° , but at all temperatures within the range of activity of the calcite.

(11) As in the case of the uranyl salts, there is complete independence between photo-phosphorescence and kathodo-phosphorescence in the sense that the one mode of excitation in no way modifies the effect of the other, even where the two are applied simultaneously.

(12) By means of a special form of disk phosphoroscope, which could be operated *in vacuo*, the earliest stages of the kathodo-phosphorescence were investigated and it was shown that from the close of excitation to the time at which, by the ordinary methods, observations begin (say half a second), the form of the curve of decay is essentially different from that pertaining to photo-phosphorescence.

TWO TYPES OF PHOSPHORESCENCE.

The discovery that the brief photo-phosphorescence of calcite from Franklin Furnace, like the still briefer photo-phosphorescence of the uranyl salts, follows a law of decay directly opposite to that of other phosphorescent substances thus far investigated, and that the law of decay of the kathodo-phosphorescence of the above calcite and of the uranyl salts is the same as that previously determined for phosphorescence in general, has led us to define two types of phosphorescence. These we term *vanishing phosphorescence* and *persistent phosphorescence*.

The distinction is not one of duration alone. The modes of decay are altogether different. In *persistent phosphorescence* the diminution of brightness is very rapid at first and becomes progressively slower in each of the successive processes of which the curve of decay is made up. In *vanishing phosphorescence* the initial rate of decay is relatively slow, but the diminution of brightness becomes progressively more rapid in each successive process. The curves of decay of the two types resemble each other in that they consist of a series of distinct parts or processes, merging into one another more or less abruptly, and that during each process the reciprocal of the square root of the intensity is a linear function of the time.

THE LUMINESCENCE OF WILLEMITES.

The phosphorescence of this brilliantly luminescent mineral is commonly of such brief duration as to elude observation unless the phosphoroscope be employed. Occasional specimens glow for a long

time after excitation, but the variety of short duration belongs to the persistent type, as appears from the curves published by Waggoner some years ago and from recent measurements of our own.

The two varieties sometimes occur in contiguous veins. They are indistinguishable during excitation by the iron spark, but upon breaking circuit the glow from one variety ceases immediately, while the other continues to shine. Mr. D. T. Wilber, in the course of experiments on the production of artificial willemite, has discovered the cause of this difference. He finds the presence of manganese essential to luminescence and that only those samples in which an abundance of zinc oxide has been used in the preparation of the silicate exhibit phosphorescence of long duration. The precise chemical relations involved are under investigation.

THE SELECTIVE RADIATION FROM ERBIUM OXIDE.

Dr. W. G. Mallory,* by way of completing his study of the selective radiation from erbium oxide, has confirmed, by an independent method, his previous determination of the striking fact that the emission bands exceed in intensity the radiation of corresponding wave-lengths from a black body of the same temperature, whereas for other parts of the spectrum the black-body radiation greatly exceeds the emission from the erbium oxide.

If we accept the well-known definition that all radiation from a substance in excess of that due to its temperature is to be regarded as luminescence, the selective radiation from erbium oxide must be so classed. The relations of its spectrum at $1,000^{\circ}$ to the similar but not identical spectrum produced by kathodo-excitation at room temperature and to the absorption spectrum have not yet been definitely determined. The very narrow absorption bands of the cold oxide occur in groups which occupy the same regions of the spectrum as the broad emission bands. The bands, both of emission and absorption, like those in the spectra of the uranyl compounds and of luminescent substances in general, form series having intervals of constant frequency.

STUDIES IN MAGNETO STRICTION.

Dr. H. A. Pidgeon has completed his extended study of the Wiedemann and Joule effects in the magnetization of specimens of iron, nickel, and cobalt, with special reference to the latter metal. The results for pure cobalt differ materially from those obtained by other observers working with impure specimens and show a remarkable similarity to the results for nickel. The twist produced by magnetization is, however, much less in cobalt than in nickel. Certain eccentricities of twist were observed in all specimens of the three metals. These have been carefully studied and discussed.

*Since the writing of this report, news has been received of the sudden death of Dr. Mallory at Oberlin, Ohio. He had been for several years an instructor in Cornell University and had recently been appointed to a professorship in physics at Oberlin College. Dr. Mallory was an investigator of great promise and his attractive personality had endeared him to all his associates.

MISCELLANEOUS.

The fine white luminescence of cadmium phosphate, prepared as prescribed by W. S. Andrews, has been examined with the disk phosphoscope and spectrometer.* This substance is excited chiefly by wave lengths too short to be transmitted through glass. The phosphorescence, though of measurable intensity only for a fraction of a second, is of the persistent type, as shown by the form of the curve of decay.

The changes of color during decay, as brought out by the phosphoscopic method of observation, are remarkable and indicate that the spectrum consists of a number of broad overlapping bands. The approximate location of these has been determined.

Data concerning the prevalence of series of constant frequency in the fluorescence and absorption spectra of substances capable of luminescence is being gathered by working up observations already published and by new measurements.

Thus recent photographs of the ultra-violet absorption spectrum of anthracene by Mr. J. M. Hyatt show the presence of two or more such series. The investigation in the case of most substances is rendered difficult by the width of the bands, which often overlap; but in all cases where it has been found possible to locate the bands series of this description have been found, and we incline to the belief that this spectral structure is characteristic of luminescence in general.

The published report of the investigation of the kathodo fluorescence of willemite by Dr. T. B. Brown,† the progress of which has been noted in previous numbers of the Year Book, contains the following conclusions:

(1) The fluorescence is directly proportional to the rate of impact of the kathode particles as measured by the current through the tube.

(2) The relation between the ratio of fluorescence to current and the electronic kinetic energy as measured by the discharge potential is non-linear, with indications of a maximum at higher potentials.

(3) There is no indication of a minimum potential below which no fluorescence would be produced.

The studies of the fluorescence of the uranyl salts at room temperature by Miss Wick‡ and of new absorption bands in the spectra of these compounds by Dr. Howes,§ referred to in the Year Book for 1917, have since been published.

During the year duties connected with the war have taken much of the time and attention of those engaged in the investigations referred to in this report. They have, however, felt it no less a patriotic duty to continue their work in pure science in such small ways as might still be possible.

* Nichols and Howes: Proc. Nat. Acad. Sci. (1918).

† Brown, T. B.: Physical Review (2), xi, 39 (1918).

‡ Wick, Frances G.: Physical Review (2), xi, 121 (1918).

§ Howes, H. L.: Physical Review (2), xi, 66 (1918).

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-16.)

The past year has seen a large amount of experimental work accomplished with a minimum of assistance, but with no publications to record. Withdrawal of students and former assistants to enter war service has given more time for personal investigation, but has limited that which could be given to preparation of material for publication. The experimental work with guinea-pigs secured in Peru in 1911 has been concluded. The single problem under investigation in mice has made good progress, so that we are now able to state definitely and quantitatively the previously demonstrated linkage between two recessive characters in mice, albinism and pink-eye. The next step is to look for other similar inter-relations among the genetic characters of mice and thus lay a foundation for a knowledge of the genetic architecture of the mammalian germ-cell. A parallel investigation with rats is in an even more promising stage, for here three characters in one linkage system have been demonstrated and the quantitative linkage relations between two of them have been fully worked out, and large stocks of rats have been bred which will soon give linkage values with the third character, and will indicate whether the grouping of genes is linear or not. A search for other linked genes in rats is also being made. A large stock of rabbits is being bred for a fuller investigation of size inheritance in mammals, a difficult problem regarding which conflicting views are still held. Special precautions are being taken to overcome the difficulties encountered in our pioneer investigations in this field made some years ago and to clear up existing uncertainties. The critical second-hybrid generation is now being produced and will be of full adult size in about one year. A possible linkage relationship of color characters in rabbits is also under investigation.

The question of the stability of genetic factors and that of the action of selection in relation to genetic change are finding satisfactory solutions in current investigations. Several minor investigations with rats and rabbits are concerned with these questions.

A favorable opportunity for the study of inheritance in relation to milking qualities of pure breeds of dairy cattle is being utilized. The experiment involves a cross between registered Holstein and registered Guernsey cattle. Full individual milk records have been secured for the foundation stock used from both pure breeds and from the F_1 hybrids. The F_2 generation will be milking next year.

INDEX.

	PAGE.		PAGE.
Acidity of Certain Mesophytic and Succulent Forms of Plants.....	64	Barnard, E. E.....	199
Adams, Walter S..... 186, 188, 194, 195, 203, 207		Barnett, S. J.....	238
Publications by.....	31, 35, 38	Publications by.....	31
Administration Building, Expenses of Maintenance of.....	27	Barus, Carl.....	v
Africa, Magnetic Work in.....	256	Investigations in Physics.....	314
African Colonization, Paper of.....	144	Publications by.....	28, 31
Agassiz, Alexander.....	iv, x	Bassett, John S.....	144
Albrecht, A.....	179	Bassett, L. E.....	299
Albrecht, Sebastian.....	180	Bassot, L.....	242
Alcohol in Tissues, Distribution of.....	224	Bauer, L. A..... v, 236, 237, 242, 261	
Alcyonaria Fauna of Reefs about Viti Levu.	167	on relation between the Secular Variation of the Earth's Magnetism and Solar Activity.....	259
Alcyonaria in the Pacific Ocean.....	163	on results of Magnetic and Allied Observations made during the Solar Eclipse of June 8, 1918.....	260
Alden, R. M.....	299	Publications by.....	31, 32
Aldrich, L. B.....	188	Report as Director of Department of Terrestrial Magnetism.....	233-268
Alkalinity of Surface Waters of Atlantic and Pacific Oceans.....	170	Beans, Studies on Variation, Correlation, and Selective Death-rate in.....	117
American Breeder's Association.....	16	Beattie, James A.....	279
American Colonies, Institutional History of.	298	Beattie, J. C.....	256
American Historical Association.....	145	Beech, A.....	248
American Historical Review.....	144	Behavior of Stomata, Investigations on...	289
American Slavery.....	144	Behre, Elinor H.....	106
Amundsen Arctic Expedition.....	240	Bell, Alexander Graham.....	17
Amylases, Chemical Investigations of.....	284	Benedict, Cornelia G..... 221, 222, 223	
Anderson, J. A..... 186, 187		Publication by.....	32
Anderson, Karl E..... 104, 105		Benedict, Francis G..... v, 116, 232	
Publication by.....	37	on a Portable Respiration Apparatus for Clinical Use.....	225
Andrews, Charles M., Historical Researches of	298	on Effects of a Prolonged Reduced Diet on Twenty-five College Men.....	225
Andrews, W. S.....	319	on Effets Physiologiques d'une Réduction Prolongée du Régime Alimentaire Expérimentée sur vingt cinq Sujets.....	229
Annelids, Report of work done on.....	171	on Energy Content of Extra Foods...	229
<i>Anton Dohrn, Yacht</i>	149	on Physiological Effects of a Prolonged Reduction in Diet on Twenty-five Men.....	228, 229
Archeology, Reports of Investigations in..	269-276	Publications by.....	28, 32, 36, 38
Articles of Incorporation.....	x-xii	Report as Director of Nutrition Laboratory.....	219-232
Asia, Magnetic Work in.....	257	Benioff, Hugo.....	188
Associates of the Institution.....	v	Bennett, A. A.....	299
Atmospheric-Electric Work of the Department of Terrestrial Magnetism.....	235	Benton, J. R.....	236
Auditing Committee for 1918.....	44	Benzold, W. von.....	242, 243
Auditors, Report of.....	46-52	Bergen, Henry.....	v
Ault, J. P..... 15, 237, 245		Work on the "Fall of Princes".....	298
on Sea Surface-Temperature and Meteorological Observations made on the <i>Carnegie</i> during her sub-Antarctic Cruise, Dec. 6, 1915, to April 1, 1916.....	259	Bichowsky, F. Russell v., Publication by...	32
Publication by.....	31	Publication on the Color of Inorganic Compounds.....	130
Avery, B. T..... 104, 114, 115, 117		Publication on Necessary Physical Assumptions underlying a proof of the Planck Radiation Law.....	129
Publications by.....	31, 32, 34	Publication on Place of Manganese in the Periodic System.....	133
Ayer, Edward E.....	146	Billings, John S.....	iv, x, xi
Ayers, Alden F.....	216		
Babcock, Harold D..... 186, 187, 215			
Baker, Marion L.....	223		
Balance Sheet.....	47		
Ball, S. C., Publication by.....	28		
Bandelier, Adolph F..... 145, 146			
Bandelier, Fanny R.....	145		
Banker, Howard J.....	125		
Banta, A. M..... 105, 106, 107, 109			
Report of Investigations of.....	106-108		
Barber, H. S.....	158		
Barker, Lewellys F.....	17		

	PAGE.		PAGE.
Biological Laboratory of the Brooklyn Institute of Arts and Sciences.....	16	Carey, Lewis R.....	150, 151
Biology, Investigations in.....	277	Publication by.....	27, 28
Bjerknes, V.....	v	Studies of the Alcyonaria of the Reefs of Samoa and Fiji.....	153
Publications by.....	32	Studies on Alcyonaria in the Pacific Ocean.....	163
Researches in Meteorology.....	300	Carnegie, Andrew.....	ix
Bjerknes, J., Publication by.....	32	Carnegie Institution, Organization, Plan, and Scope.....	ix
Blakeslee, Albert F.....	114, 117	<i>Carnegie</i> , 12, 234, 235, 240, 247, 248, 255, 256, 259, 264, 265, 266, 267.	
Publications by.....	32, 34, 35, 39	Voyages of in 1917-1918.....	233
Studies of Plant Genesis.....	114	Carpenter, Thorne M.....	221, 223, 224
Blood, Alice F.....	222	Publication by.....	28
Bog and Swamp Waters.....	66	Carruth, W. H.....	299
Boles, Inza A.....	221	Carter, Edna.....	188, 214
Booth, Basil.....	276	Carty, John J.....	iii, iv
Boss, Benjamin.....	v	Case, E. C.....	v
Publication by.....	32	Paleontological Investigations of.....	310
Report as Director of Department of Meridian Astrometry.....	173-180	Publications by.....	32
Boss, Lewis, Publication by.....	28	Cash, James R.....	99, 100, 101
Botanical Research, Report of Department of.....	55-88	Publication by.....	32
Bowditch, N., on American Practical Navigator.....	265	Castle, W. E.....	v
Bowen, N. L., Publication by.....	32	Heredity in Small Mammals.....	320
Publication on Crystals of Barium Disilicate in Optical Glass.....	132	Cathode Luminescence, Production of Spectra by.....	214
Publication on the Significance of Glass-making Processes to the Petrologist.....	132	Catterall, Mrs. R. C. H.....	144
Bowes, Catherine.....	139	Cepheid Variables, some Spectral Characteristics of.....	211
Bowman, H. H. M., Publication by.....	28	Chamberlin, T. C.....	v
Boyer, Sylvester.....	282, 283	on Fundamental Problems of Geology..	297
Bramble, C. C.....	299	Chambers, Alfred A., Publication by.....	27
Brayton, Ada M.....	188, 215	Chancellor, John.....	149
Bridges, Calvin B.....	277	Chaucer, Preparation of a Concordance to..	299
Publications by.....	32, 36	Chemistry, Investigations in.....	279-286
Brookings, Robert S.....	iii, iv, 3, 4, 44	Chittenden, Russell B.....	228
Brooklyn Institute, Biological Laboratory of.....	120	Chow, Ming.....	279
Brown, Frederick.....	236, 257	Publication by.....	36
Brown, T. B.....	319	Chree, Charles.....	242
Publication by.....	32	Christchurch Magnetic Observatory.....	13
Bryan, William Alanson.....	158	Churchill, William.....	v
Buffum, Grace I.....	180	Cipriani, Arthur H.....	149
Burdick, Charles L.....	279	Clark, Livia C.....	180
Publication by.....	32	Clark, Victor S.....	140
Burnett, E. C.....	143, 147	Clements, Edith, on Grazing Research....	296
Burns, Carolyn.....	188	on Permanent Quadrats.....	295
Burns, Helen.....	188	on Variation and Mutation in <i>Epilobium</i>	293
Burns, Margherita.....	188, 215	Clements, Frederic E.....	312
Burwell, Cora G.....	188	Investigations in Ecology.....	287-298
By-laws of the Institution.....	xiii-xvi	on Climatic Cycles.....	295
Cacti, Carbohydrate Economy of.....	61	on Climax Formations.....	294
Cadwalader, John L.....	iv, x	on Experimental Pollination.....	293
Cady, W. G.....	314	on Field and Garden Study of Genera and Species.....	294
Calorific Value of Extra Foods.....	222	on Grazing Research.....	296
Calorimeter for small Animals and Infants, Reconstruction of.....	220	on Indicator Plants.....	296
Cameron, Alfred E.....	79	on Light Measurements.....	291
Campbell, Irvin H.....	139	on Permanent Quadrats.....	295
Cannon, Gertrude L., Preliminary Report of a Study of Heredity in Insanity in the Light of the Mendelian Laws.....	123	on Photosynthetic Efficiency.....	289
Cannon, W. A., on Modification of Root Habits by Experimental Means....	83	on Phytometer Method.....	288
on Root-Growth in Desert Plants and Oxygen Supply of the Soil.....	81	on Reciprocal Transplants.....	292
Publications by.....	32	Climatic Cycles.....	295
Carbohydrate Economy of Cacti.....	61	Coble, Arthur B., Publication by.....	32
		Cold-blooded Animals, Metabolism of.....	222
		Collins, A. W.....	158

	PAGE.		PAGE.
Colloidal Phenomena in the Protoplasm of		Davenport, Charles B.— <i>Continued.</i>	
Pollen Tubes.....	67	on Study of Human Heredity.....	123
Colloids and Cell-Masses, Hydration and		on Trait Book.....	123
Growth of.....	68	on Reply to Criticism of Recent Ameri-	
Colonies in America, Preparation of a General		can Work by Dr. Heron, of the	
History of.....	298	Galton Laboratory.....	123
Color of Stars, Investigation of.....	203	Publications by.....	28, 32, 33, 36
Coloration of Hawaiian Brachyura and		Publication on the Feebly Inhibited....	123
Fishes.....	158	Publication on the Hill Folk.....	123
Concordance to Chaucer.....	299	Publication on the Nam Family.....	123
Congress, Library of.....	140, 141, 144	Report as Director of Eugenics Record	
Conrad, H. S., on Hereditary Fragility of		Office.....	119-126
Bone (<i>fragilitas osseus, osteopsathy-</i>		Report as Director of Department of	
<i>rosis</i>).....	123	Experimental Evolution.....	103-118
Conradt, C. C.....	158	Davenport, Frances G.....	143, 147
Continental Congress, Letters of Delegates to	143	Davis, Arthur L.....	279
Contributions to Embryology.....	28	Davis, Helen.....	188
Cook, Captain James.....	14, 233, 262, 263	Publications by.....	33, 38
Cooke, C. Montague.....	153, 158	Davis, Paul B., Publication by.....	28
Cooke, George A.....	153, 158	Day, Arthur L.....	v, 132
Corals, Growth Rate of.....	152	Report as Director of Department of	
Coral Reefs of Pago Pago Harbor.....	165	Geophysical Laboratory.....	127-138
Coral Reefs of Samoa.....	168	Death Losses of the Year.....	18
Cotton, Henry A., on Some Problems in the		Deel, S. A.....	236
Study of Heredity in Mental		Dendrograph, A New Instrument for record-	
Diseases.....	123	ing Growth and other Variations	
Covert, Mildred S.....	125	in the Dimensions of Trees.....	59
Cowdry, E. V.....	95	<i>Discovery</i> , Vessel.....	262
Publication by.....	28	Dockham, Arthur S.....	187, 188
Publication concerning the Mitochond-		Dodge, Cleveland H.....	iii, iv, x, 3, 44
rial Constituents of Protoplasm..	91	Dodge, Raymond.....	231, 232
Cowdry, N. H.....	95	Dodge, William E.....	iv
Publication by.....	32	Dole, Richard B., Publication by.....	27
Craig, W. M.....	281, 282	Donnan, Elizabeth.....	139, 143, 144, 147
Crane, Charles W.....	85	Doran, Mabel I.....	180
Creak, Ettrick W.....	235, 243	Douglass, A. E., on Climatic Cycles.....	295
Cushman, Joseph A., Publication by.....	27	Dowd, Merritt C.....	218
Cytology.....	93	Duesberg, Jules.....	95, 96
Dahlgren, Ulric, a Study of Luminous Insects	157	Publications by.....	33
Study of Luminous Organs in Insects..	153	Duncan, John C.....	188
Dalton, James.....	216	Publication by.....	33, 38
Daniels, Josephus.....	150	Duvall, C. R.....	236, 237, 257
Danielson, Florence H., Publication on the		Dyer, Mabel A.....	180
Hill Folk.....	123	Early English Literature, Work in.....	298
Davenport, Charles B.....	v, 17	Eclipse Operations of Department of Terres-	
on Eugenics.....	123	trial Magnetism.....	235
on Family-history Book.....	123	Ecology, Investigations of F. E. Clements	287-298
on Feebly-inhibited: Violent Temper		Ecology, Report of Desert Botanical Labora-	
and Its Inheritance.....	123	tory on.....	76
on First Study of Inheritance in		Edmonds, H. M. W.....	15, 245, 248, 249
Epilepsy.....	123	on instructions issued by France and	
on Hereditary Factor of Pellagra.....	123	United States concerning Protec-	
on Hereditary Fragility of Bone (<i>fragi-</i>		tion of Cook's third expedition,	
<i>litas osseus, osteopsathyrosis</i>).....	123	returning to England.....	262
on Heredity in Relation to Eugenics...	123	on preliminary results of Ocean Mag-	
on Heredity of Skin-color in Negro-		netic Observations on the <i>Carnegie</i>	
white Crosses.....	123	from Balboa.....	261
on how to make a Eugenical Family		on preliminary results of Ocean Mag-	
Study.....	123	netic Observations on the <i>Carnegie</i>	
on Inheritance of Stature.....	123	from Buenos Aires to Talcahuano.	261
on Naval Officers: Their Heredity and		on preliminary results of Ocean Mag-	
Development.....	123, 126	netic Observations on the <i>Carnegie</i>	
on Neurofibromatosis.....	126	from Talcahuano to Balboa.....	261
on State Laws limiting Marriage Selec-		Publication by.....	33
tion examined in the light of		Edmunds, C. K.....	257
Eugenics.....	123	Effect of Bog and Swamp Waters on Plants	
		and on Biocolloids.....	66

	PAGE.		PAGE.
Egg-production, Biometric Studies on.....	117	Flügel, Ewald.....	299
Elder, E. W.....	236, 257	Forstemann, Ernst.....	276
Electric-Furnace Investigations.....	214	<i>Fortune</i> , U. S. S.....	150
Ellerman, Ferdinand.....	186, 187, 188, 189, 196, 197	Fowler, H. W., Publication by.....	28
Publications by.....	33, 34, 37	Fox, Dixon R.....	298
Ellis, James H., Publication by.....	32	Fox, Edward L.....	222
Elster, J.....	243	Franklin, Benjamin.....	14, 262, 263
Energy Requirements of Normal Individuals.....	222	Frazer, J. C. W.....	v
Ennis, C. C.....	236, 238	Free, E. E., Publication by.....	33
Embryology, Report of Department of.....	89-102	Freed, E. S.....	279
Epilobium, Variation and Mutation in.....	293	Frew, William N.....	iv, x
Erbium Oxide, Selective Radiation from.....	318	Fuller, Alice M.....	180
Ericksen, A.....	248	Fundamental Problems of Geology.....	297
Estabrook, Arthur H.....	124, 125	Gage, Lyman J.....	iv, x
Publication on the Jukes in 1915.....	123	Galactic Planes in Globular Clusters.....	205
Publication on the Nam Family.....	123	Galbraith, Esther E.....	140, 143
Eugenical News.....	124	<i>Galilee</i>	13, 234, 264, 265, 266, 267
Eugenics Record Office, Gift of.....	15, 16	Gann, Thomas.....	269
Eugenics Record Office, Report concerning.....	119-126	Garard, I. D., Publications by.....	33, 38
Eugenics Research Association.....	124	Garrison, Fielding H., Report on Preparation and Publication of Index Medicus..	276
Eugenics, Training Course for Field-Workers.....	124	Gas Interchange in Certain Succulents.....	63
European Treaties bearing on the History of the United States.....	143	Gas-mask, Physiological Application of Modern.....	224
Executive Committee for 1918.....	44	Gay, Duncan.....	149, 150, 172
Executive Committee, Report of.....	41-45	Geitel, H.....	243
Experimental Evolution, Department of.....	16	Geobotany of the Santa Lucia Mountains..	78
Experimental Evolution, Report of Depart- ment of.....	103-126	Geology, Investigations in.....	297
Fenner, C. N., on the Effect of certain Im- purities in causing Milkiness in Optical Glass.....	138	Geophysical Laboratory, Production of Optical Glass by.....	9
Publication by.....	33	Geophysical Laboratory, Report concerning Operations of.....	127-138
Fenner, Charles P.....	iii, iv, 3	Gibbs Memorial Laboratory.....	279
Ferguson, John B., a Note on the Sintering of Manganese.....	138	Gibbs, Willard.....	128, 129
on Effect of certain Impurities in caus- ing Milkiness in Optical Glass.....	138	Gilman, Daniel C.....	iv, x, xi
Publication on an Improved Form of Thermo-regulator.....	133	Goddard, Henry H., on Heredity of Feeble- mindedness.....	123
Publication on Equilibrium between Carbon Monoxide, Sulfur Dioxide, and Free Sulfur.....	134	on Study of Human Heredity.....	123
Publication on Melting-points of Cristo- balite and Tridymite.....	134	Goldfarb, A. J., Publication by.....	33
Publication on Temperature Uniformity in an Electric Furnace.....	133	Goldman, Marcus I., Publication by.....	27
Publications by.....	33, 36	Goodman, J. T.....	276
Finance Committee for 1918.....	44	Grant, Madison, President of Eugenics Re- search Association.....	124
Financial Administration of the Institution.....	xvi	Grant, Sherwood B.....	179, 180
Financial Records of the Institution.....	22	Grazing Research.....	296
Financial Statement for Fiscal Year 1917- 1918.....	23	Green Coronal Line at 1918 Eclipse.....	194
Finlayson, Anna W., Publication on Dack Family.....	123	Greene, Elizabeth F.....	140
Finn, Mary D.....	222	Greene, Evarts B.....	140
Fisher, Irving.....	17	Growth in Higher Plants.....	58
Fisk, H. W.....	236, 237, 257	Growth of Plants.....	55-57
on Results of Magnetic and Allied Ob- servations made during the Solar Eclipse of June 8, 1918.....	260	Growth-rates of Alcyonaria at Pago Pago... Gudger, E. W.....	163 150
Publication by.....	33	Publications by.....	28, 33
Fleming, J. A.....	238, 241	Publication on Spider-web and Spider- web Fish Nets.....	154
on latest annual values of Magnetic Ele- ments at Observatories.....	263	Publication on the Myth of the Ship- holder.....	154
Publication by.....	33	Guide to Materials in Paris.....	147
Flexner, Simon.....	iv	Hackett, Charles W.....	145, 146
		Hale, George E.....	v
		Publications by.....	33, 34, 37, 39
		Report as Director of Mount Wilson Observatory.....	181-218
		Hall, H. M., on Field and Garden Study of Genera and Species.....	294

	PAGE.		PAGE.
Hall, H. M., on Reciprocal Transplants.....	292	Howe, Marshall A., Publication by.....	27
on Rubber-producing Plants.....	297	Howe, William Wirt.....	iv, x
Harriman, Mrs. E. H.....	16, 119	Howes, H. L., Publications by.....	35, 36
Harris, J. Arthur.....	221	Huff, C.....	241
Investigations of.....	116-118	Human Metabolism, Comparative Work on.....	118
on Osmotic Concentrations of Tissue		Hunt, Gaillard.....	140
Fluids in relation to Geographical		Hunter, Andrew.....	221
Distribution.....	86	Hutchinson, Charles L.....	iii, iv, x, 4, 44
Publications by.....	32, 34, 35, 37	Hyatt, J. M.....	319
Harvey, E. Newton.....	149, 153	Hydration and Growth of Colloids and of	
on Chemistry of Light Production in		Cell Masses.....	68
Cypridina.....	154	Imbibition and Water Relations of Plants... 66-86	
Publication by.....	34	Imbibition of Water by Gelatin.....	74
Publication on Studies on Biolumine-		Index Medicus.....	27, 29
scence, IV. The Chemistry of Light		Report on Preparation and Publication.....	276
production by the Firefly, VI. Light		Ingalls, N. W., Publication by.....	27
Production by a Japanese Permat-		Publication concerning a Human Em-	
ulid, <i>Cavernularia haberi</i> . What		bryo before the Appearance of the	
substance is the Source of Light in		Myotomes.....	91
the Firefly.....	154	Instrument Shop at Mount Wilson.....	216
Studies on Bioluminescence, VIII. The		Investigation in Stars of Nebulæ.....	198-213
Mechanism of the Production of		Investments of Institution, Schedule of.....	49
Light during Oxidation of Pyro-		Investments in Property of the Institution..	26
gallol.....	154	Ishikawa, C.....	154
Study of Chemistry of Light-producing		Ivens, Walter G., Publication by.....	28
Substances in Marine Animals.....	153	Jacomini, Clement.....	216
Haskins, Charles H., Publication by.....	34	James, Mary B.....	180
Hatai, S., Publication by.....	34	Jameson, J. Franklin.....	v
Publication on Brain-Weight in relation		Report as Director of Department of	
to the Body-length and also to the		Historical Research.....	139-147
Partition of Non-protein Nitrogen		Jean, F. C., on Phytometer Method.....	288
in the Brain of the Gray Snapper..	154	Jenkins, Heroy.....	179, 180
Hawaiian Brachyura and Fishes.....	158	Jesuit Observatory at Lukiapang.....	236
Hay, John.....	iv, x, xi	Johns, C. O.....	115
Hay, Oliver P.....	v	Johnson, Alice.....	222
Investigations in Paleontology.....	311	Johnson, Duncan S., Publication by.....	28
Publications by.....	34	Johnstone, E. R., on Study of Human	
Hayford, John F.....	v	Heredity.....	123
Hedrick, Henry B., Publication by.....	28	Jones, B.....	248, 249
Heckendorn, C.....	248	Jones, Bertha W.....	180
Held, John.....	269	Joslin, Elliott P.....	220
Henderson, Lawrence J.....	280	Joy, Alfred H.....	188, 189, 191, 210
Hendry, Mary F.....	222	Publications by.....	31, 35
Herbert, Allen.....	158	Joyner, Mary C.....	188
Heredity in Small Mammals, Studies of....	320	Judson, Sarah E., Publication by.....	36
Herrick, Myron T.....	iii, iv	Jung, G. H.....	241
Hewitt, Abram S.....	iv	Jupiter's Ninth Satellite.....	200
Hewlett, C. W.....	236	Kapteyn, J. C.....	v, 184, 187, 201
Publication by.....	34	Publication by.....	35
Higginson, Henry L.....	iii, iv, x	Kennedy, A. G.....	299
Hines, Marion.....	101	Kernahan, Harold.....	149
Publication by.....	34	Key, Wilhelmine E.....	125
Historical Geography of United States,		Publication by.....	35
Atlas of.....	141, 147	King, Arthur S.....	187, 214
Historical Research, Report of Department..	139-147	Publication by.....	35
Historical Service, National Board for....	136, 146	Kinney, H. S.....	216
History, Researches in.....	298	Kippis, A.....	262, 263
Hitchcock, Ethan A.....	iv, x	Kirkpatrick, William F.....	117
Hitchcock, Henry.....	iv	Publications by.....	32, 34, 35
Holmes, Mary J.....	106	Kitson, Arthur.....	262
Hosmer, G. L.....	236, 258	Knight, Frederic H.....	221
Hostetter, J. C., Publications by.....	35, 38	Knipp, C. T.....	236, 258
Publication on a Silica-glass Mercury		Koch, John C.....	98
Still.....	127	Publication by.....	35
Howe, Henry M.....	v	Koch, Mathilda L.....	105
Investigations in Metallurgy.....	315	Publications by.....	35, 37

	PAGE.		PAGE.
Kotterman, C. A.	239	Longley, W. H., study of Relation of Color and Color-pattern of Reef Fish in their Environment.....	153
Kozu, S., Publications by.....	35, 39	Lorz, J. G.	241
Publication on Augite from Stromboli..	132	Lothrop, S. K.	276
Kuehne, J. M.	236, 258	Low, Seth.....	iv, x
Kunitomo, Kanae.....	102	Lowe, Elias A.	v
Publication by.....	28	Lukiapang, Jesuit Observatory at.....	236
Publication concerning the Development and Reduction of the Tail and of the Caudal end of the Spinal Cord....	91	Luminescence in Calcite.....	316
La Mer, Victor K., Publications by.....	35, 37	Luminous Insects, a Study of.....	157
Land Magnetic Work of Department of Terrestrial Magnetism.....	235	MacDougal, Daniel T.	v
Land Work of Department of Terrestrial Magnetism.....	256	on Culture of a Potato Hybrid.....	87
Lange, Isabella.....	180	on Dendrograph, a new Instrument for recording Growth and other Variations in Dimensions of Trees.....	59
Lange, Marie.....	180	on Development of Conceptions included in Growth.....	55
Langley, Samuel P.	iv, x	on Effect of Bog and Swamp Waters on Plants and on Biocolloids.....	66
Larsen, L.	248	on Growth of Mechanism of Protoplasm on Hydration and Growth of Colloids and of Cell-Masses.....	68
Laughlin, Harry H.	17, 120	on Nature and Course of Growth in Higher Plants.....	58
on Durations of the Several Mitotic Stages in the Root-tip of the Onion	126	on Origin and Physical Basis of Succulence in Plants.....	85
on how to make a Eugenical Family Study.....	123	Publications by.....	35, 37, 38
on Modification of the 9:3:3:1 Ratio..	126	Report as Director of Department of Botanical Research.....	55-88
on report of first twenty-seven months' work of the Eugenics Record Office..	123	MacDowell, E. Carlton.....	103, 110
on Study of Human Heredity.....	123	Report of Investigations of.....	109
Publication by.....	35	MacInnes, Duncan A.	279
Studies of the Committee on Sterilization	123	Macklin, C. C.	98
Lawrence, John V.	85, 116	Publication by.....	35
Publications by.....	34, 35	MacNeill, Frances L.	180
Leaves, Apparatus for determining the Temperature of.....	80	MacNeill, Helen M.	180
Leland, W. G.	139, 140, 147	MacVeagh, Wayne.....	iv, x
Lewis, Margaret Reed.....	93, 95	McClendon, J. F.	168
Publication by.....	35	Publications by.....	28, 36
Lewis, Warren H.	93	Publication on Effect of Stretching upon the rate of Conduction in the Neuromuscular Network in <i>Cassiopea</i>	154
Publication by.....	35	Publication on Effect of Oxygen Tension on the Metabolism of <i>Cassiopea</i> ...	154
Light, Measurements of.....	291	Publication on Diurnal Changes in the Sea at Tortugas.....	154
Lindsay, William.....	iv, x	McCollum, E. V.	115
Literature, Work of the Carnegie Institution in.....	298-299	McDermott, F. A.	158
Lloyd, Francis E., on Colloidal Phenomena in the Protoplasm of Pollen Tubes..	67	McDowell, Louise S., Publications by.....	36, 39
on Colloidal Properties of Certain Plant Mucilages.....	72	McFadden, J. M.	248, 249
on Effect of Potassium and Sodium on Hydration and Growth.....	67	McGee, J. M.	66
on Mucilage of <i>Opuntia</i> , <i>Abutilon</i> , and <i>Oenothera</i>	71	Magnetic Observatory, Work of Department of Terrestrial Magnetism.....	236
on Water-Content and Abscission in the Nuts of <i>Juglans californica quercina</i>	76	Magneto Striction, Studies in.....	318
Publications by.....	35	Mall, Franklin P.	18, 89, 90, 91, 99
Lodge, Henry Cabot.....	iii, iv, 3	Publication by.....	35
Loftfield, G. V., on Behavior of Stomata....	289	Mallory, W. G.	318
on Grazing Research.....	296	Mann, Albert, Publication by.....	27
on Permanent Quadrats.....	295	Marine Biology, Report of Department of	149-172
Long, Frances, on Experimental Pollination.	293	Mascart, E.	243
on Photosynthesis and Respiration.....	60	Matteson, David M.	143
on Photosynthetic Efficiency.....	289	Mauchly, S. J.	236, 238, 239, 241, 257, 260
on Rubber-Producing Plants.....	297	on Study of Pressure and Temperature Effects in Earth-current Measurements.....	263
Longley, W. H., on Habits and Coloration of Hawaiian Brachyura and Fishes, with a note on the Possibility of Submarine Color-photography.....	158		

	PAGE.		PAGE.
Mauchly, S. J., on results of Magnetic and Allied Observations made during the Eclipse of June 8, 1918.....	260	Mogenson, Anne, on Transpiration of Trees.....	290
Publication by.....	35	Morley, Frank.....	v
Mayor, Alfred G.....	v	Application of Cremona Groups to the Solution of Algebraic Equations....	299
Effect of High Temperature on the accumulation of Acid in the Tissues.....	154	Morley, Sylvanus, G.....	v
Formula for Rate of Nerve-conduction in Sea-water.....	154	Report on Archeological Investigations.....	269-276
Memoir of William Stimpson.....	154	Morrow, William W.....	III, IV, x, 3
Navigation illustrated by Diagrams....	154	Morse, H. N.....	v
on Alkalinity of Surface Waters of Atlantic and Pacific Oceans.....	170	Motor Adjustments, Recorder for Adequacy.....	220
on Growth-rate of Samoan Coral Reefs.....	168	Moulton, F. R.....	v
Publications by.....	27, 28, 35	Mount Wilson Observatory, Report on Operations of.....	181-218
Report as Director of Department of Marine Biology.....	149-172	Mucilage of <i>Opuntia</i> , <i>Abutilon</i> , and <i>Oenothera</i>	71
Report upon <i>Scyphomedusæ</i> collected by U. S. Bureau of Fisheries steamer <i>Albatross</i>	154	Mucilages of Certain Plants, Colloidal Properties of.....	72
Study of Siphonophores of West Indies.....	153	Muncey, Elizabeth B., Huntington's Chorea, on study of Heredity of Pellagra in Spartanburg County.....	123
Meetings of Board of Trustees.....	xiii	Munro, Dana C.....	140
Mendel, Lafayette B.....	v	National Research Council.....	181, 215, 237
Publications by.....	36	Nebulæ and Star-Clusters, Spectroscopy of.....	212
Researches in Nutrition.....	302-310	Nelson, A. Louise.....	125
Meridian Astrometry, Report of Department of.....	173-180	Neumayer, G.....	243
Merrymon, W. W.....	236	Neun, D. E., Publications by.....	36, 38
Merwin, H. E., Publications by.....	33, 36	New Mexico, Internal Affairs of.....	146
Publication on the Melting-points of Cristobalite and Tridymite.....	134	North America, Magnetic Work in.....	257
Publication on the Ternary System.....	132	Nova Aquilæ No. 3.....	210
Metabolism of Cold-blooded Animals.....	222	Noyes, Arthur A.....	v
Metabolism of Normal Children.....	221	Chemical Investigations of.....	279
Metabolism with varying Environmental Temperatures.....	221	Publication by.....	36
Meteorology, Researches in.....	300	Nichols, E. C.....	215
Metz, Charles W.....	103, 109	Nichols, Edward L.....	v
Publication by.....	36	Investigations of properties of matter through a wide range of Temperature.....	316
Meyer, Arthur N.....	89, 91, 92	Publication by.....	36
Publication by.....	36	Nicholson, Seth B.....	187, 188, 189, 191, 200
Meyer, H.....	267	Publication by.....	36
Miles, Walter R.....	220	Nueva Galicia, Affairs of.....	146
on the Effect of Alcohol on Psycho-Physiological Functions.....	231	Nueva Vizcaya, Affairs of.....	146
on the Effects of a Prolonged Reduced Diet on Twenty-five College Men.....	225	Nutrition Laboratory, Investigations concerning Effects of Short Rations....	225
Publications by.....	28, 32, 36	Nutrition Laboratory, Report of.....	219-232
Mills, Darius O.....	iv, x	Nutrition, Researches by Osborne and Mendel.....	302-310
Mills, John.....	149, 150, 151	Ocean Magnetic Observations from December 1917 to June 1918.....	249-255
Minutes of Seventeenth Meeting of Board of Trustees.....	1-4	Ocean Magnetic Work of <i>Galilee</i> and <i>Carnegie</i>	234
Mississippi Valley, History of.....	147	Ocean Work of Department of Terrestrial Magnetism.....	247
Mitchell, S. Weir.....	iv, x, xi	Officers of Institution for Year 1918.....	iii
Moll, E.....	266	O'Gara, P. J.....	289
Morey, George W., Publications by.....	36, 40	One-Hundred-Inch Telescope at Mount Wilson.....	217
Publication on Pressure-temperature Curves in Monovariant Systems....	128	Optical Glass, Production of.....	9
Publication on Solubility and Fusion Relations at High Temperatures and Pressures.....	138	Optical Shop at Mount Wilson.....	216
Publication on the Laws of Equilibrium.....	128	Ordnance Department of War Department..	315
Montague, Andrew J.....	iii, iv	Orr, Florence I., a Study of Heredity of Insanity in the light of the Mendelian Theory.....	123
Morgan, T. H.....	v, 17	Osborne, Thomas B.....	v
on Constitution of Germ-plasm in relation to Heredity.....	277	Publications by.....	36, 39
Publication by.....	36	Researches in Nutrition.....	302-310
		Osgood, Herbert L.....	v, 19
		Historical Researches of.....	298
		Osmotic Concentration of Vegetable Saps... ..	114

	PAGE.		PAGE.
Oxygen Content of Surface-water of the Pacific Ocean.....	167	Proper Motions, Measurement and Parallaxes of.....	200
Radial Velocities.....	208	Protoplasm, Growth Mechanism of.....	57
Rankin, G. A., Publications by.....	36	Publications Authorized and Issued during Year.....	27
Publication on the Ternary System....	132	Publications of Eugenics Record Office... 123-125	
Ratnowsky, Simon.....	130	Publications of Department of Terrestrial Magnetism.....	259-268
Rats of Alcoholic and Non-Alcoholic Parentage, Studies of.....	109-114	Publications, Growth and Extent of.....	29
Raymond, Harry.....	179, 180	Publications of Nutrition Laboratory....	225-232
Publication by.....	37	Publications, Sales of.....	29
Raymond, W. J.....	236, 258	Pueblo Indians of the Southwest.....	145
Paleontology, Investigations in.....	310-314	Pulfrich, C.....	266
Parkinson, W. C.....	237	Real Estate and Equipment, Schedule of... 52	
Parliament, Proceedings and Debates Respecting North America.....	143	Receipts and Disbursements for 1918.....	48
Parmelee, James.....	III, IV, 3	Receipts and Disbursements of Institution from Organization to Date.....	45
Parsons, Wm. Barclay.....	III, IV, 3, 44	Receipts and Expenditures of Institution to Date, Summary of.....	24
Paton, Stewart.....	III, IV, 3, 44	Report of Executive Committee.....	41-45
Paullin, C. D.....	139, 141, 147	Report of President of Institution.....	5-40
Peabody, Dorothy A.....	221	Researches of the Year.....	20
Pease, Francis G.....	187, 212, 215	Research Information Service.....	181
Publication by.....	36	Resolution, Vessel.....	262
Peckham, Leslie E.....	124	Respiration Apparatus and Breathing Appliances for Human Subjects.....	223
Pennypacker, John Y.....	85	Respiration Chamber for Treadmill Observations.....	220
Pepper, George W.....	III, IV	Respiration Rates of Samoan Aleyonaria... 164	
Period-Luminosity Curve of Cepheid Variations.....	204	Richards, H. M.....	85
Peru, Observatory in.....	237	on Acidity of Certain Mesophytic and Succulent Forms of Plants.....	64
Peters, W. J.....	15, 236, 237	on Gas Interchange in Certain Succulents.....	63
on Results of Dip-of-horizon Measurements on <i>Galilee</i> and <i>Carnegie</i>	264	Publication by.....	37
Publication by.....	36	Richards, Theodore W.....	v
Pfister, Bertha.....	125	Chemical Investigations of.....	279-284
Phillips, P. Lee.....	140	Publications by.....	37, 40
Phosphorescence, Two Types of.....	317	Richmond, Myrtle L.....	188
Photographic Magnitudes for Selected Areas	201	Riddle, Oscar.....	103, 109
Photographs of Nebulae and Clusters.....	199	Publications by.....	34, 35, 37
Photometry of Star Clusters.....	204	Report of Investigations of.....	104
Photosynthesis and Respiration.....	60	Ritchey, George W.....	187, 216
Photovisual Magnitudes for Selected Areas.. 203		Publication by.....	37
Physical Laboratory at Mount Wilson.....	213	Rolph, F. W.....	221
Physics, Investigations in.....	314-319	Root, Elihu.....	III, IV, X, XI, 3, 46
Phytometer Method in Ecology.....	288	Chairman of Board of Trustees.....	43
Phyotosynthetic Efficiency, Investigations in	289	Root-growth in Desert Plants and Oxygen Supply of the Soil.....	81
Pidgeon, H. A.....	318	Root Habits, Modification of.....	83
Piper, C. V.....	114	Root Systems, Ecology of.....	291
Plant Breeding.....	87	Rosonoff, A. J., on Reply to Criticism of Recent American work by Dr. Heron, of the Galton Laboratory.....	123
Plant Genesis, Studies of.....	114	on Study of Heredity in the light of the Mendelian Theory.....	123
Plants, Growth of.....	55-57	Preliminary Report of a Study of Heredity in Insanity in the light of the Mendelian Laws.....	123
Pollen Tubes, Colloidal Phenomena in Protoplasm of.....	67	Roth, Paul.....	221
Pollination, Experimental.....	293	on the Effects of a Prolonged Reduced Diet on Twenty-five College Men.. 225	
Pond, Clara P.....	125	Publications by.....	32, 37
Potassium and Sodium, Effect on Hydration and Growth.....	67	Roy, Arthur J.....	179, 180
Potato Hybrid.....	87	Publication by.....	37
Potter, Frederick A.....	158	Rubber Producing Plants.....	297
Power, A. D.....	248, 249	Rücker, Arthur.....	243
Poyer, John M.....	150		
Preiser, Samuel A., Publication by.....	36		
Publication on Neurofibromatosis.....	126		
President of the Institution, Powers and Duties of.....	XIV		
President of Institution, Report of.....	5-40		
Pritchett, Henry S.....	III, IV, 3, 44		

	PAGE.		PAGE.
Ryerson, Martin A.	III, IV, 3	Sosman, Robert B.— <i>Continued.</i>	
Sabin, Florence R.	99	Publication on a Silica-Glass Mercury	
Publication by.	37	Still.	127
Sales of Publications and Value of those on		Publication on work of the Geophysical	
hand.	29	Laboratory.	133
Sameshima, J.	281	South America, Magnetic Work in.	258
Samoan Coral Reefs, Growth-rate of.	168	Southard, E. E.	17
Sanford, Roscoe F.	180, 187, 212	Spoehr, H. A., on Carbohydrate Economy of	
Santa Lucia Mountains, Geobotany of.	78	Cacti.	61
Sarton, George.	v	on Origin and Physical Basis of Succu-	
Savary, G. R.	248	lence in Plants.	85
Sawyer, H. E.	235, 256, 257	on Photosynthesis and Respiration.	60
Schafer, Joseph.	140	Publication by.	38
Schultz, Adolf H.	93, 96	Spectroscopic Determinations of Luminosity	
Publication by.	37	and Parallax.	209
Schumm, Walter C.	280	Spectroscopy of Nebulae and Star-Clusters. .	212
Schuster, A.	243	Spooner, John C.	IV, x
Scott, H. D.	269	Squier, E. G.	276
Scott, W. E.	248, 249	Standardizing Magnetic Observatory.	237
Scudder, Mary T.	104	Star-Streaming, Theory of.	206
Publication on Naval Officers: Their		Statistical Theory, Miscellaneous Studies in. .	117
Heredity and Development.	126	Stearns, Carl L.	179, 180
Silvester, Charles F., Publication by.	28	Stebbins, Joel.	197
Skonberg, E. K.	241	Steiner, W. F.	241
Slave Trade, American.	143	Stellar Luminosities and Absolute Magni-	
Smith, A.	241	tudes.	176
Smith, Edgar F.	v	Stellar Motions.	176
Chemical Investigations of.	286	Stellar Parallaxes.	174
Publication by.	28	Stellar Photometry.	200
Smith, H. Monmouth, on Effects of a Pro-		Stellar Spectroscopy.	207
longed Restricted Diet on Twenty-		Sterilization Studies.	125
five College Men.	225	Sterling, Allen.	236, 258
Publications by.	32, 38	Stewart, Charles W.	144
Smith, M. B.	236, 239, 257, 258	St. John, Charles E., 186, 187, 188, 189, 194, 195, 215	
Smith, Theobald.	III, IV	Publications by.	31, 38
Smithsonian Institution.	260, 261	Stock, Leo.	139, 143, 147
Sodium and Potassium, Effect on Hydration		Strange, H. Pinckney.	149
and Growth.	67	Streeter, George L.	v, 4
Soil-Temperature Survey of United States		Publication concerning the Develop-	
and Canada.	79	mental Alterations in the Vascular	
Solar and Stream Motion, Determination of	209	System of the Brain of the Human	
Solar Eclipse of June 8.	195	Embryo.	91
Solar Rotation.	193	Publication concerning the Histogenesis	
Seares, Frederick H.	187, 201, 203, 204	and Growth of the Otic Capsule and	
Publications by.	34, 37, 38, 39	its contained Periotic Tissue-spaces	
Shapley, Harlow, 187, 188, 200, 201, 203, 204, 209, 212		in the Human Embryo.	91
Publications by.	31, 37, 39	Publications by.	27, 28, 38
Sherman, H. C.	v	Report as Acting Director of Depart-	
Chemical Investigations of.	284	ment of Embryology.	89-102
Publications by.	33, 36, 38, 39, 40	Stromberg, Gustaf.	187, 209
Shreve, Edith B., on Apparatus for deter-		Publications by.	31, 38
mining the Temperature of Leaves		Strum, L. W.	150
on Geobotany of the Santa Lucia Moun-		Sturtevant, A. H.	277
tains.	78	Publications by.	28, 38
on Imbibition of Water by Gelation. . .	74	Submarine Color-photography.	158
on Index of Transpiring Power of Plants	72	Succulence in Plants, Origin and Physical	
Publication by.	38	Basis of.	85
Shreve, Forrest, on Soil-Temperature Survey		Sun, General Magnetic Field of.	191
of United States and Canada.	79	Sun-Spot Polarities.	189
on Vegetation of an Imperfectly Drained		Sun-Spots, Inclination of Lines of Force in. .	190
Desert Valley.	76	Sun-Spots, Relation between Field-Strength	
Shull, George H.	87	and Size of.	191
Shumway, Bertha M.	188	Surrey, N. M. Miller.	141
Sosman, Robert B., Publications by.	35, 38	Sutton, R.	236, 257

	PAGE.		PAGE.
Sverdrup, H. U.....	300	Walker, J. A., Publications by.....	38, 39
Publication by.....	39	Wallis, W. F.....	237, 256
Swamp and Bog Waters.....	66	War, Participation of the Institution.....	7
Swann, W. F. G.....	238	Ware, Louise W.....	195
Publications by.....	39	Publication by.....	38
Taft, William H.....	iv	Warner, D. E.....	117
Talbot, Fritz B.....	221	Publications by.....	32, 39
on Energy Metabolism of an Amaurotic		Washington, Henry S., Publications by.....	35, 39
Family Idiot.....	229	Description of the Quantitative Classifi-	
Publication by.....	39	cation of Igneous Rocks.....	135
Tanguy, L. L.....	248, 249	Manual of the Chemical Analysis of	
Tatlock, John S. P.....	v	Rocks.....	136
Report upon Preparation to a Concord-		Publication on Augite from Stromboli..	132
ance to Chaucer.....	299	Publication on Calculation of the Ration-	
Temperature of Leaves, Apparatus for de-		al Analysis of Clays.....	136
termining.....	80	Publication on Chemical Analysis of	
Terrestrial Electricity.....	238	Igneous Rocks.....	132
Terrestrial Magnetism, Report of Depart-		Publication on Italian Leucitic Lavas as	
ment of.....	233-268	a sort of Potash.....	131
Terrestrial Magnetism, Research Work in		Water Relations of Plants.....	66-86
Washington.....	237	Watson, Ernest M.....	100, 110
Thayer, Ethel H.....	125	Publication by.....	39
Thomson, A.....	236, 257	Wave-Length Investigations.....	194
Thompson, John W.....	160	Wave-Length, Secondary Standards of.....	215
Tittman, O. H.....	243	Weaver, J. E.....	289
Tobago.....	149	on Ecology of Root Systems.....	291
Tokyo, Zoological Laboratory of Imperial		on Phytometer Method.....	288
University of.....	154	on Transpiration of Trees.....	290
Transpiration of Trees.....	290	Weeks, David F., on a First Study of Inheri-	
Transpiring Power of Plants.....	72	tance in Epilepsy.....	123
Treadwell, A. L.....	149, 150	on Study of Human Heredity.....	123
Report on work on Annelids in 1918...	171	Weinstein, Alexander.....	109
Study of the Eunicidæ of Coral Reefs..	153	Welch, Donald S.....	104
Trees, Transpiration of.....	290	Welch, William H.....	III, IV, 3, 17
Troy Book, Work on Glossary of.....	298	Wells, Roger C., Publication by.....	27
Trustees of Institution.....	xiii	Western Australia, Investigations in.....	236
Trustees of Institution, Present and Former.		Wheeler, Theodora.....	92
Trustees, Minutes of Seventeenth Meeting		Publication by.....	27
of Board of.....	1-4	Study of a Human Spina Bifida Mon-	
Tuthill, Tracy E.....	124, 125	ster with Encephaloceles and other	
Van Deman, Esther B.....	v	Abnormalities.....	91
van der Bilt, J., Publications by.....	38, 39	White, Andrew D.....	iv, x
Van Der Stricht, O., Publication by.....	27	White, E. Grace, Publication by.....	28
Publication concerning the Genesis and		White, Edward D.....	iv
Structure of the Membrana Tectoria		White, Henry.....	III, IV
and the Crista Spiralis of the		White, Walter P., a note on a Universal	
Cochlea.....	91	Switch for Delicate Potential Meas-	
Van Haagen, Walter K., Publication by...	28	urements.....	135
Van Maanen, Adriaan.....	187, 193, 200	on some points regarding Calorimeter	
Publications by.....	34, 37, 39	Efficiency.....	135
Van Wagenen, Bleeker.....	126	Publication by.....	39
Variable Stars.....	207	Publication on Calorimetric Lag.....	137
Varnum, William B.....	149, 179, 180	Publication on Calorimetric Methods	
Vaughan, Thomas Wayland, Publications by	27, 39	and Devices.....	137
Vegetable Saps, Osmotic Concentration of..	116	Publication on Conditions of Calorime-	
Vegetation of an Imperfectly Drained		tric Precision.....	136
Desert Valley.....	76	Publication on General Character of	
Vicari, Emilie.....	103, 109	Specific Heats at High Tempera-	
Virginia Historical Society.....	143	tures.....	138
Wahlin, H. B.....	236, 258	Publication on Heat Convection in Air	
Wakeman, Alfred J., Publications by.....	36, 39	and Newton's Law of Cooling.....	127
Walcott, Charles D.....	III, IV, x, XI, 3	Publication on Specific Heat of Plati-	
Chairman of Executive Committee for.		num at High Temperatures.....	135
1918.....	43	Publication on Thermal Leakage and	
Vice-Chairman of Board of Trustees...	44	Calorimeter Design.....	131
Walcott, Henry P.....	III, IV, 3		

	PAGE.		PAGE.
Whitman, Charles Otis.....	109	Wilson, John H.....	158
Publication by.....	32	Wilson, Woodrow.....	182
Wick, Frances G., Publications by.....	36, 39	Winn, Lucile.....	188
Wickersham, George W.....	III, IV, 3, 4, 44	Winters, J. C., Publications by.....	38, 40
Widmer, J. A.....	241	Wise, D. M.....	236, 239, 245, 257, 258
Wieland, George E.....	v	Wolfe, Coral.....	188, 193
Investigations in Paleontology.....	312	Woodward, Robert S.....	III, IV, 3
Publications by.....	39	Report as President of the Institution..	5-40
Wilber, D. T.....	318	Wright, Carroll D.....	IV, X, XI
Publications by.....	36, 39	Yerkes, R. M.....	124
Willard, Florence.....	115	Y. M. C. A. College of Springfield.....	12
Willemite, Luminescence of.....	317	Yngve, Victor, Publications by.....	37, 40
Williams, J. Whitridge.....	89	Young & Company, Auditors.....	43
Publication by.....	40	Report for 1918.....	46-52
Williamson, Erskine D., Publications by....	36, 40	Yucatan, Archeological Investigations in..	269-276
Publication on Pressure-temperature		Zoology, Investigations in.....	320
Curves in Monovariant Systems...	128		
Publication on the Laws of Equilibrium	128		





WH 1A2T 5

